CALIFORNIA ENERGY COMMISSION

Small HVAC Problems and Potential Savings Reports

Summary of Problems in Each Building (product 4.5.1)

Statewide Energy Impact (product 4.5.3)

TECHNICAL REPORT

October 2003
500-03-082-A-25

STATE OF CALIFORNIA
ENERGY COMMISSION

Gray Davis, *Governor*

CALIFORNIA ENERGY COMMISSION

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ACKNOWLEDGEMENTS

The products and outcomes presented in this report are part of the **Integrated Design of Small Commercial HVAC Systems** research project. The reports are a result of funding provided by the California Energy Commission's Public Interest Energy Research (PIER) program on behalf of the citizens of California. Architectural Energy Corporation would like to acknowledge the support and contributions of the individuals below:

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Technical Advisory Group (TAG): Tudi Hassl of Portland Energy Conservation, Inc. (PECI), Jan Johnson of Southern California Edison, John Proctor of Proctor Engineering Group, Richard Lord of Carrier Corporation, Dr. Mark Modera of Carrier Aeroseal.

Architectural Energy Corporation Project Team: Pete Jacobs led the project, with AEC staff support from Dave Roberts, Tracy Phillips, Erik Jeanette, John Wood, Matthew Potts, Kosol Kiatreungwattana, Pablo Calderon-Rodriguez and Judie Porter. RLW Analytics as a subcontractor provided field testing and engineering support and statistical analysis, including contributions from Roger Wright, Matt Brost, Jeff Staller, Eric Swan, Amber Watkins and Stacia Okura. Eskinder Berhanu, Principal of Eskinder Berhanu Associates also provided field testing and engineering support.

Additional Support: Alan Cowan and Jeff Johnson of New Buildings Institute, project technical review and Design Guide review; Darren Goody of PECI, Design Guide Review.

PREFACE

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

This document is one of 33 technical attachments to the final report of a larger research effort called *Integrated Energy Systems: Productivity and Building Science Program* (Program) as part of the PIER Program funded by the California Energy Commission (Commission) and managed by the New Buildings Institute.

As the name suggests, it is not individual building components, equipment, or materials that optimize energy efficiency. Instead, energy efficiency is improved through the integrated design, construction, and operation of building systems. The *Integrated Energy Systems: Productivity and Building Science Program* research addressed six areas:

- Productivity and Interior Environments
- Integrated Design of Large Commercial HVAC Systems
- Integrated Design of Small Commercial HVAC Systems
- Integrated Design of Commercial Building Ceiling Systems
- Integrated Design of Residential Ducting & Air Flow Systems
- Outdoor Lighting Baseline Assessment

The Program's final report (Commission publication #P500-03-082) and its attachments are intended to provide a complete record of the objectives, methods, findings and accomplishments of the *Integrated Energy Systems: Productivity and Building Science Program*. The final report and attachments are highly applicable to architects, designers, contractors, building owners and operators, manufacturers, researchers, and the energy efficiency community.

This attachment, "Small HVAC Problems and Potential Savings Reports" (Attachment A-25), provides supplemental information to the program's final report within the **Integrated Design of Small Commercial HVAC Systems** research area. It includes the following reports:

1. **Summary of Problems in Each Building.** This report describes the underlying causes of faults or suboptimum performance in the small package HVAC units in each monitored building, along with appendices.

2. **Statewide Energy Impact.** The focus of the Integrated Design of Small Commercial HVAC Systems project was system-integration issues affecting the installed efficiency of small packaged HVAC systems, defined as single package rooftop air conditioners and heat pumps with cooling capacity of 10 tons or less. This report provides estimates of the statewide energy-savings impacts of correcting the performance problems uncovered during this research project, along with appendices.

The Buildings Program Area within the Public Interest Energy Research (PIER) Program produced these documents as part of a multi-project programmatic contract (#400-99-413). The Buildings Program includes new and existing buildings in both the residential and the non-residential sectors.

The program seeks to decrease building energy use through research that will develop or improve energy efficient technologies, strategies, tools, and building performance evaluation methods.

For other reports produced within this contract or to obtain more information on the PIER Program, please visit www.energy.ca.gov/pier/buildings or contact the Commission's Publications Unit at 916-654-5200. All reports, guidelines and attachments are also publicly available at www.newbuildings.org/pier.

ABSTRACT

The "Small HVAC Problems and Potential Savings Reports" consists of two reports produced by the Integrated Design of Small Commercial HVAC Systems project. This was one of six research projects within the *Integrated Energy Systems: Productivity and Building Science* Program, funded by the California Energy Commission's Public Interest Energy Research (PIER) Program.

This project conducted short-term monitoring of packaged HVAC systems up to 10 tons per unit, identified problems that lead to poor system performance, and recommended solutions. A total of 215 units at 75 sites were monitored. This attachment consists of two documents:

- **Summary of Problems in Each Building.** Describes the causes of suboptimum performance in the small package HVAC units in each monitored building
- **Statewide Energy Impact.** Estimates of the statewide energy-savings impacts of correcting the performance problems. The analysis concluded that:
    - If the recommendations in the *Design Guide* developed as part of this project were adopted, average building electricity savings would be 8%. Natural gas savings would be 30%. Combined average energy cost savings would be $0.26/ft².
    - If new buildings in California adopted the *Design Guide's* recommendations, the following statewide energy savings could be achieved (assuming 10% market penetration the first year and an increase of 1% per year over the next 10 years).
        - First-year electricity savings: 6,942 MWh. Cumulative savings over 10 years: 496,360 MWh ($68 million).
        - First-year natural gas savings: 97,107 therms. Cumulative savings over 10 years: 6,943,000 therms ($5.8 million).
        - Total savings over 10 years: $73.8 million.

Author: Pete Jacobs, Architectural Energy Corp.

Keywords: packaged HVAC system, economizer, RTU, thermostat, DX air conditioner, refrigerant charge, cycling fans, ventilation air, simultaneous heating and cooling, statewide energy savings

Integrated Energy Systems Productivity & Building Science Program

A project of the State of California PIER Program

Element Four – Integrated Design of Small Commercial HVAC Systems

Summary of Problems Observed in Field Studies of Small HVAC Units

Deliverable for Task 4.5.1

INTRODUCTION

This document presents a summary of the results of the field studies conducted for Element 4 of the New Buildings Institute Integrated Energy Systems - Productivity & Building Science Program. The focus of Element 4 is system integration issues affecting the installed efficiency of small packaged HVAC systems. For the purposes of this project, small systems are defined as single package rooftop air conditioners and heat pumps with cooling capacity of 10 tons or less.

FIELD TESTING

To conduct this research, teams of engineers visited 75 newly constructed commercial buildings throughout California. A total of 215 rooftop units were surveyed. Units were subjected to a physical inspection, a series of one-time tests, and/or short-term monitoring of unit performance. Up to four units per building were selected for study.

Sites were selected at random to represent a cross-section of statewide new construction activity. The population was defined using a listing of new construction projects obtained from F. W. Dodge. The Dodge database seeks to list all new construction projects that are valued over $200,000 and are expected to start within 60 days. The data include renovations and expansions as well as entirely new buildings.[1] These data were filtered to exclude projects not in the scope of this study, such as roads, bridges, public works, and so on. New construction, as defined in this study, included buildings that were "green field" new construction, additions or major "gut" renovations. Projects four years old or newer were included in the study. A sample of projects representative of California non-residential new construction was selected based on a sample size of 82 total projects. The actual study sample compared with the original sample design is shown in Figure 1. A list of the sites in the study is shown in Appendix A.

[1] The data are thought to cover over 95% of all projects that are competitively bid.

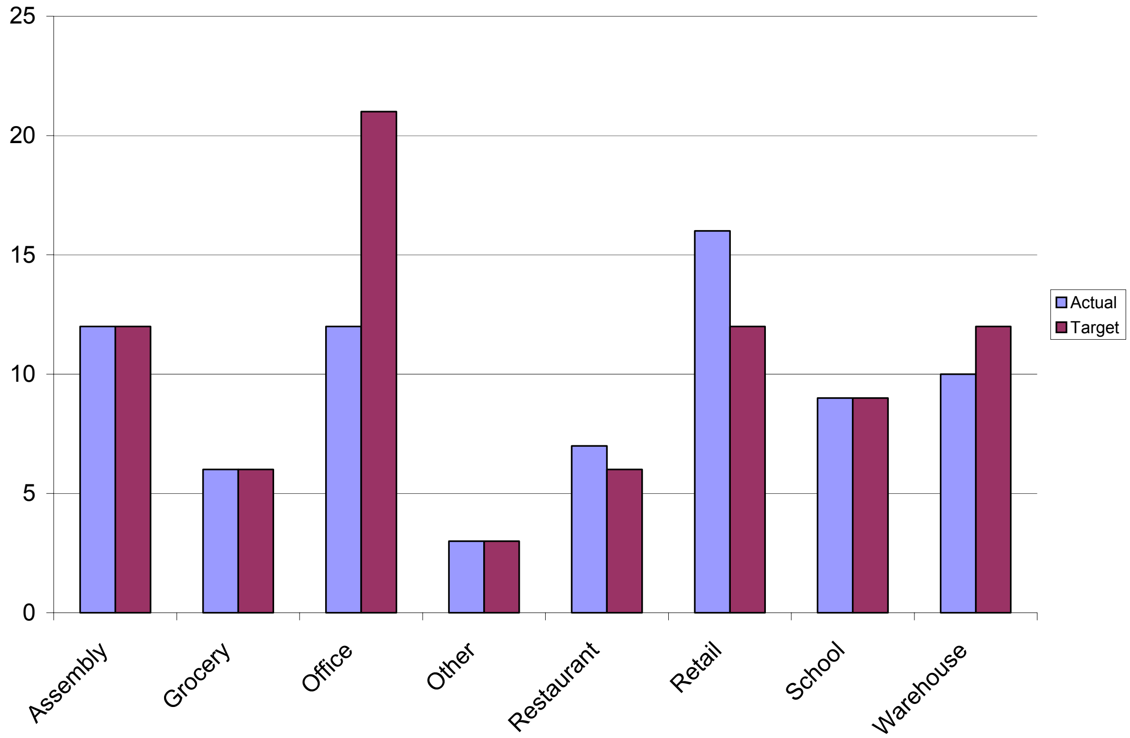

Figure 1. Sample design and Actual Building Sample

The initial study design called for all sites to be completed during the summer and fall of 2001. Difficulty in scheduling on-site surveys in the wake of the September 11, 2001 terrorist attacks delayed the project, forcing a second round of site studies during the summer of 2002. The sample was completed for most building types except for offices, which were difficult to identify and recruit. The reduced sample size is not expected to impact the statistical validity of the results, since the frequency of the problems observed is quite high and independent of building type.

Lessons learned during round one lead to a revision in the field testing and data analysis protocol for round two sites. Initially, the impacts of problems observed were to be calculated for each of the 82 buildings in the study, and the results of the impacts for this sample would be projected to the statewide level. The focus in round two was shifted from studying the entire building, including the HVAC system to a more detailed study of the HVAC system alone. The field work was used to estimate the frequency of problems in the field, and the impact of these problems across a wide variety of building types and sizes was estimated using the Statewide Non-Residential New Construction (NRNC) database (RLW, 1999). The statewide estimates of energy impacts from avoiding the problems was estimated by applying the study statistics across a sample of 990 new commercial buildings in the NRNC database. This approach allowed for a more detailed study of the HVAC systems and a more robust estimate of the statewide impacts than the original study design. See the Impact Analysis report (AEC, 2003) for more information on the statewide impact estimation process.

Field Testing for Round One.

Field testing was conducted in two rounds. The first round procedures are described as follows:

Onsite survey

The on-site survey gathered information on building shell, lighting, internal loads, operating schedules, and so on, sufficient to develop a DOE-2 model of each space served by the treated units. Building characteristics data were entered into a Microsoft Access database by the surveyor.

One-time tests

The second level of data collection involved a series of one-time tests conducted on the units selected for study. These tests included:

Fan Power. The unit was cycled through each mode of operation (standby, fan-only, cooling stage one, and cooling stage two, if applicable) and the true electric power and current of the unit were measured during each mode using a portable wattmeter.

Economizer. If the unit had an airside economizer, the minimum outdoor air position potentiometer was adjusted to test the operation of damper motors and linkages. The economizer outdoor air temperature sensor was cooled down using a "cool" spray, thus simulating cool outdoor air conditions. The response of the economizer was observed as the sensor was cooled, as shown in Figure 2.

Figure 2. Cool spray (see red tube to left of “D” on damper assembly) used to cool down outdoor temperature sensor

Short Term Monitoring

Selected units were monitored over a two to three week period using portable, battery-powered data loggers to observe unit operation over a variety of operating conditions. The datalogger was used to measure unit current, supply air temperature, return air temperature, and mixed air temperature. The data were observed instantaneously and stored on a five minute basis. The datalogger used thermistor sensors with a 0.5°F accuracy over the full range. The current sensors were equipped with signal conditioning equipment to provide true RMS current readings. True RMS current measurements were coupled with the spot kW and current measurements to estimate time series kW data for the unit. In addition to the datalogger installed at each unit, the local rooftop temperature and humidity was monitored at each site. Diagnostic software was used to analyze the short-term monitored data.

Figure 3. Unit prepared for short term monitoring using battery powered datalogger.

Field Testing for Round 2

The second round of testing focused less on the building characteristics and more on the quantitative nature of the problems with the systems. A series of new diagnostic tests were introduced in lieu of a full on-site survey of the building.

An interview with the site contact on building operations and maintenance procedures was conducted. Thermostat make and model numbers were collected to see if the thermostats were appropriate for commercial building applications. The thermostat control settings were observed and the calibration of the thermostat sensor was checked. Thermostat location was noted and compared to the spaces served by the system.

Fan flow and Power

The unit was cycled through each mode of operation (standby, fan-only, cooling stage one, and cooling stage two, if applicable) and the true electric power and current of the unit were measured during each mode using a portable wattmeter. Airflow rate was measured using a flow grid, which is an averaging flow meter designed to be installed in place of the filters. A digital micromanometer measures the pressure drop across the plate, and reads out directly in cfm. The manometer was also used to measure supply static pressure, return static pressure, and total unit external static pressure.

Figure 4. Flow Grids used to measure unit flow rate. Flow grid assembly and digital micromanometer are shown on the left. Flowgrid installation in place of unit filters is shown on the right.

Refrigerant charge

Service gauges and temperature sensors were used to verify the state of charge of the rooftop unit using the CheckMe![1] Procedure. The high side and low side pressures were measured, along with the suction line temperature, the condensed liquid temperature, outdoor drybulb temperature entering the condenser, and drybulb and wet bulb temperatures entering the evaporator coil. Refrigerant was added or removed from the system until the suction line superheat on units with fixed metering devices, or the condenser line approach or subcooling temperature on units with thermostatic expansion valves (TXV) was within the target specified by the CheckMe! software.

Figure 5. Refrigerant gages and digital temperature meter set up in preparation for conducting CheckMe test.

FINDINGS SUMMARY

The NBI Pier project identified a number of problems with HVAC systems as they are installed and operated in the field. Problems identified include broken economizers, improper refrigerant charge, fans running during unoccupied periods, fans that cycle on and off with a call for heating and cooling rather than providing continuous ventilation air, low air flow, inadequate ventilation air, and simultaneous heating and cooling. General construction and maintenance issues, such as dirty filters and coils and construction defects were also noted. A summary of the findings from the study is shown in Figure 6.

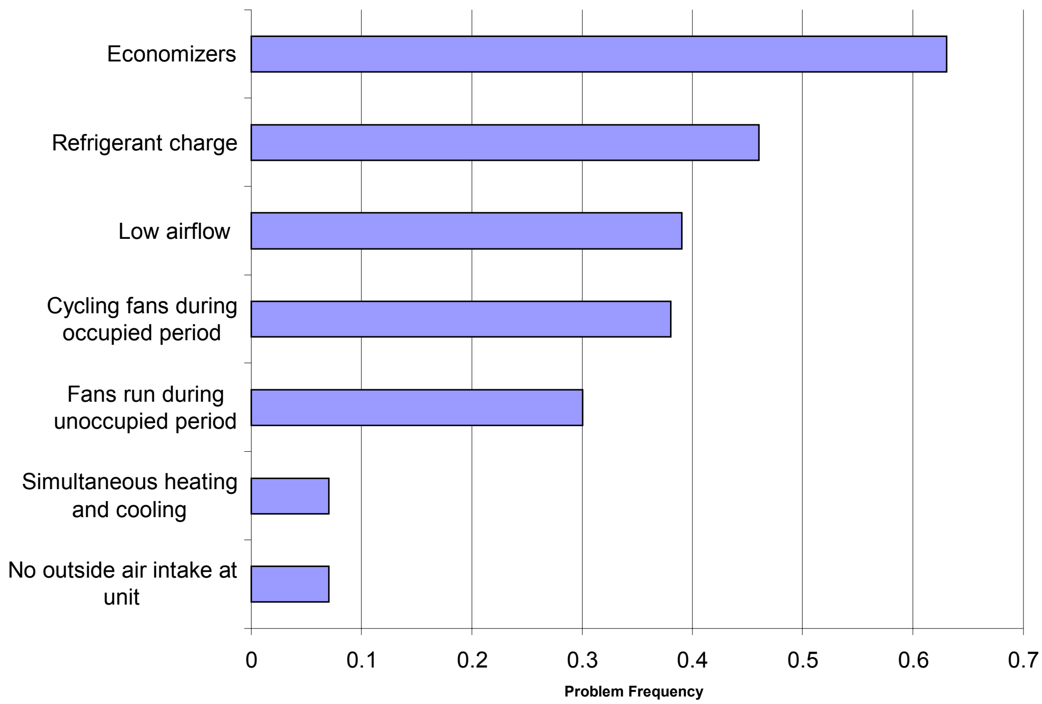

Figure 6. Summary of Field Findings from Element 4 Field Research.

Economizer Findings

Economizers show a high rate of failure in the study. Of the 215 units tested, 123 units were equipped with economizers. Of these, 30 units (24%) would not move at all, 49 units (40%) either did not respond to the cold spray test or did not modulate during the short-term monitoring period.

Differential enthalpy economizers were the most popular style: 49 of the 123 units (40%) were differential enthalpy, followed by single point temperature (23%), single point enthalpy (21%) and differential temperature (16%).

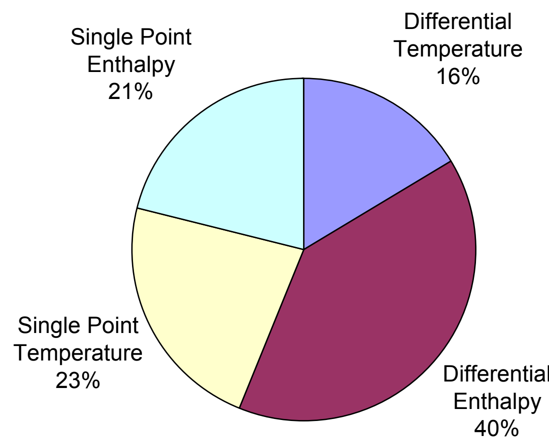

Figure 7. Economizer Control Type Distribution

According to the Title 24 Energy Standards, single point enthalpy economizers should use the "A" changeover setpoint, but the "D" setpoint was most common. The D setpoint was used in 10 of the 25 (40%) single point enthalpy systems. The D setting causes the economizer to change from outdoor air cooling to compressor cooling at the lowest outdoor air enthalpy of the A – D settings, thus limiting the economizer hours of operation and energy savings potential.

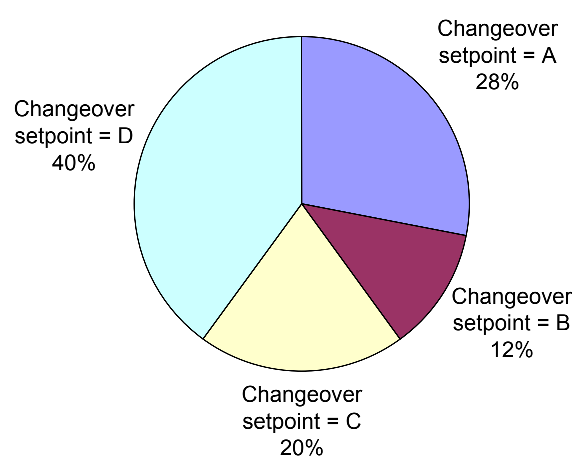

Figure 8. Distribution of Changeover Setpoints on Single Point Enthalpy Economizer Controllers

Refrigerant Charge

Target superheat, subcooling or approach temperatures were tested using the CheckMe! procedure. Any test not meeting the target temperature within five degrees failed the screening test. Of the 74 refrigerant tests, 33 (46%) did not pass the screening test. Refrigerant was added or removed from the system until the target value was reached. The charge variation was calculated based on the weight of refrigerant adjustment compared to the total refrigerant charge. A frequency distribution of the charge levels observed in the study is shown in Figure 9.

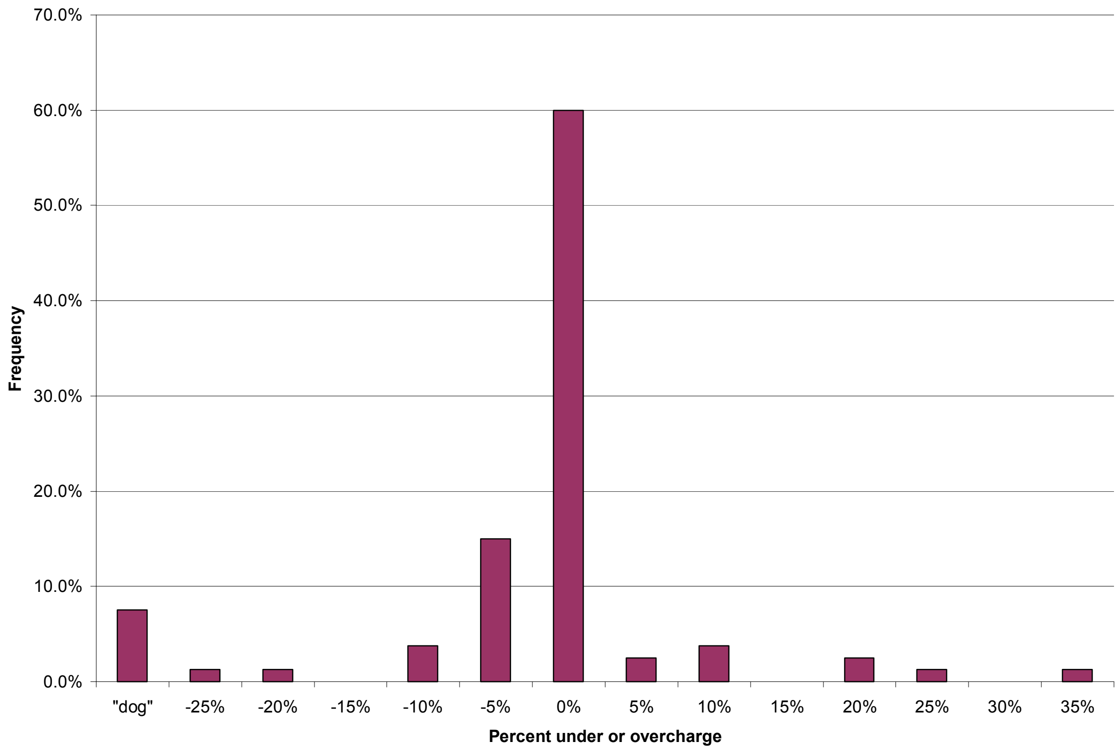

Figure 9. Frequency Distribution of Refrigerant Charge Levels

The energy impact of the charge variation was calculated according to Proctor (2002). The average energy impact (not including units that were fully discharged and obviously leaking) was about 5% of the annual cooling energy.

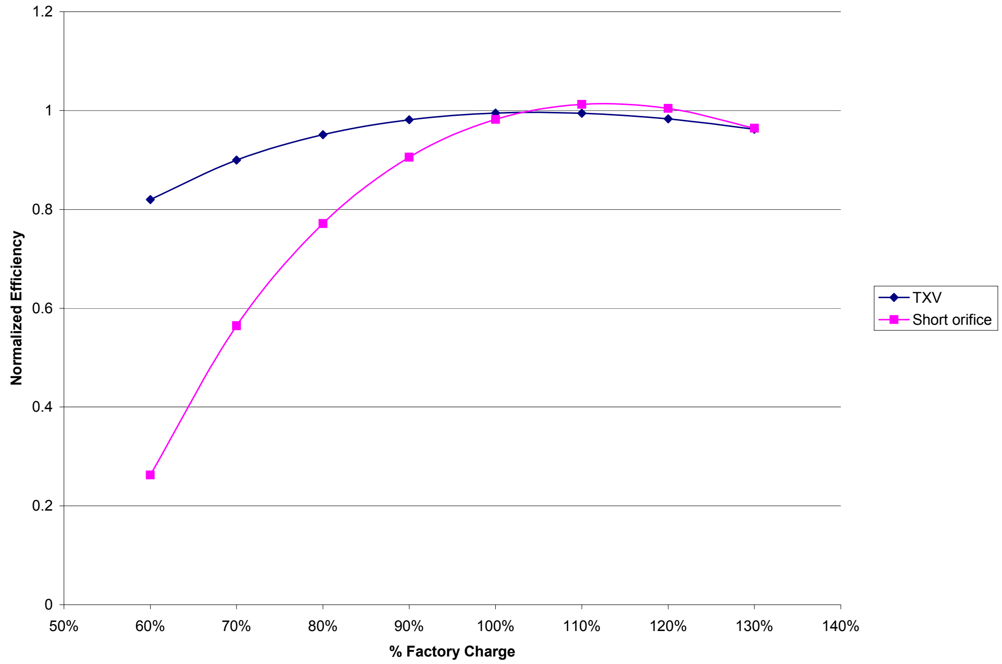

Figure 10. Impacts of Refrigerant Charge Levels on System Efficiency for Fixed and TXV Expansion Devices (Proctor, 2002).

Air Flow and Fan Power

Units were tested for in-situ airflow using flow grids. The distribution of the measured airflow is shown in Figure 11.

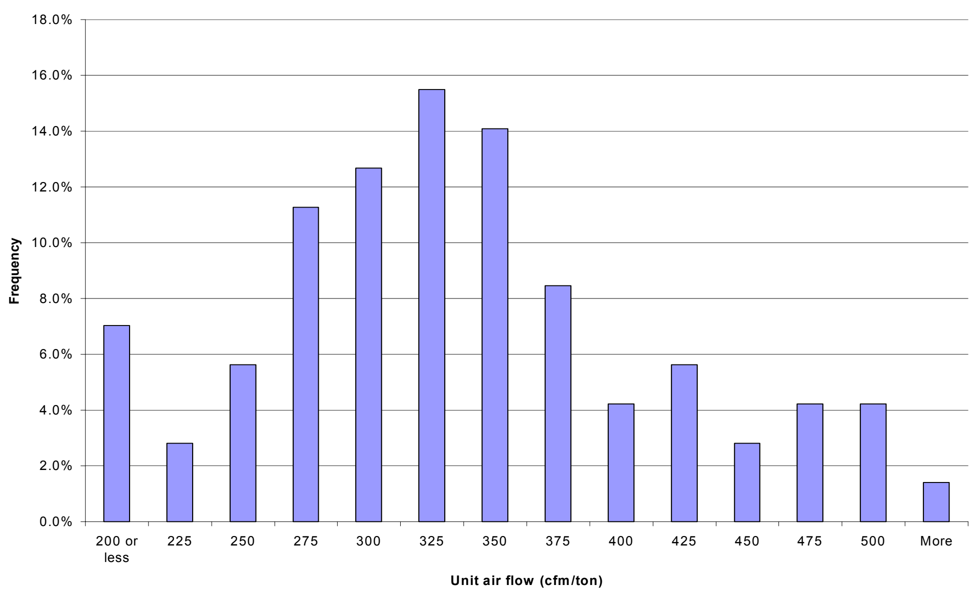

Figure 11. Measured Airflow Distribution.

Overall, of the 79 units tested for airflow, 28 (39%) had airflow less than 300 cfm/ton. The average airflow rate was 325 cfm/ton. ARI standards are based on airflow rates of 400 cfm/ton. The annual energy impact of low airflow on cooling efficiency was projected across the sample of units using the relationship in Figure 12 (Proctor, 2002). Overall the impact of low air flow is about 9% of the annual cooling energy.

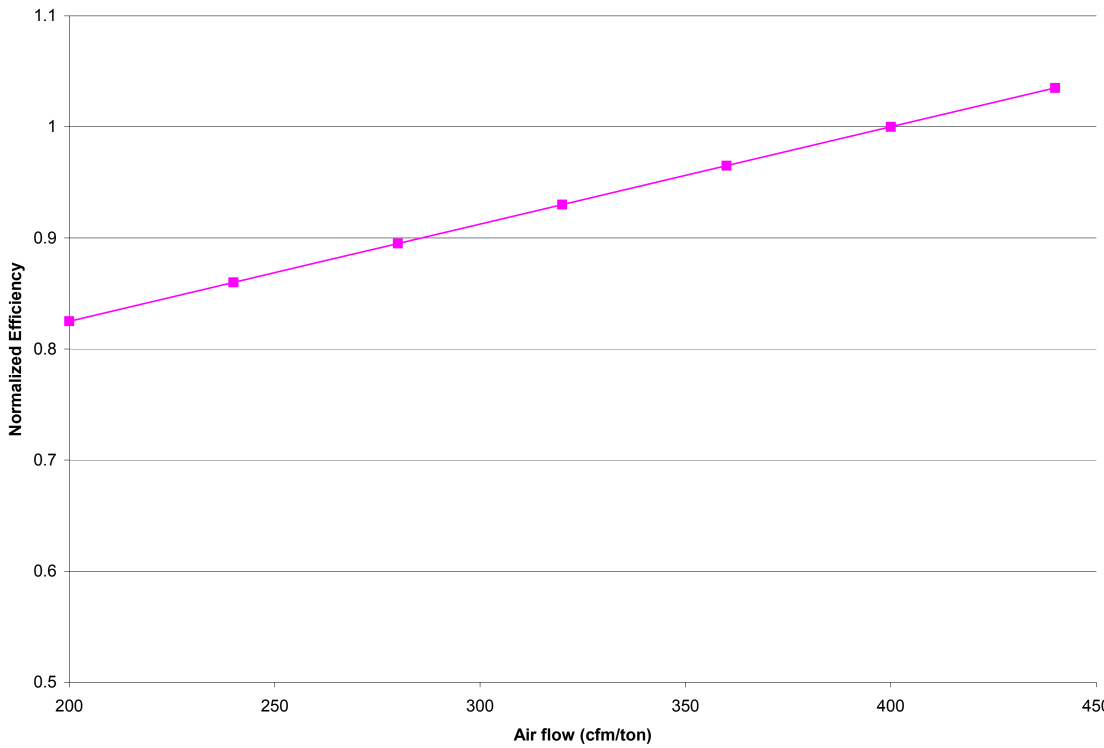

Figure 12 Impact of Supply Air Flowrate on Unit Efficiency (Proctor, 2002).

The average measured fan power for all units in the study was 0.18 kW per nomimal cooling ton, which is about 20% higher than the fan power assumed in the Title 24 energy standards (0.365 W/cfm @ 400 cfm/ton or 0.146 kW/ton). If the fan flow is increased to 400 cfm/ton, the fan power will increase to 0.34 kW/ton. This increase effectively drops the efficiency of a 10.3 EER unit to 9.1.

The combination of high fan power and low flow rate is due largely to excessive pressure drop in the duct systems. The frequency distribution of unit external static pressure at the measured flow rate is shown in Figure 13. The average duct system pressure drop was 0.48 in WC. ARI efficiency ratings assume a duct system pressure drop of 0.1 to 0.25 in WC, depending on the system size. The average duct system pressure drop corrected to 400 cfm/ton would equal 0.625 in W.C.

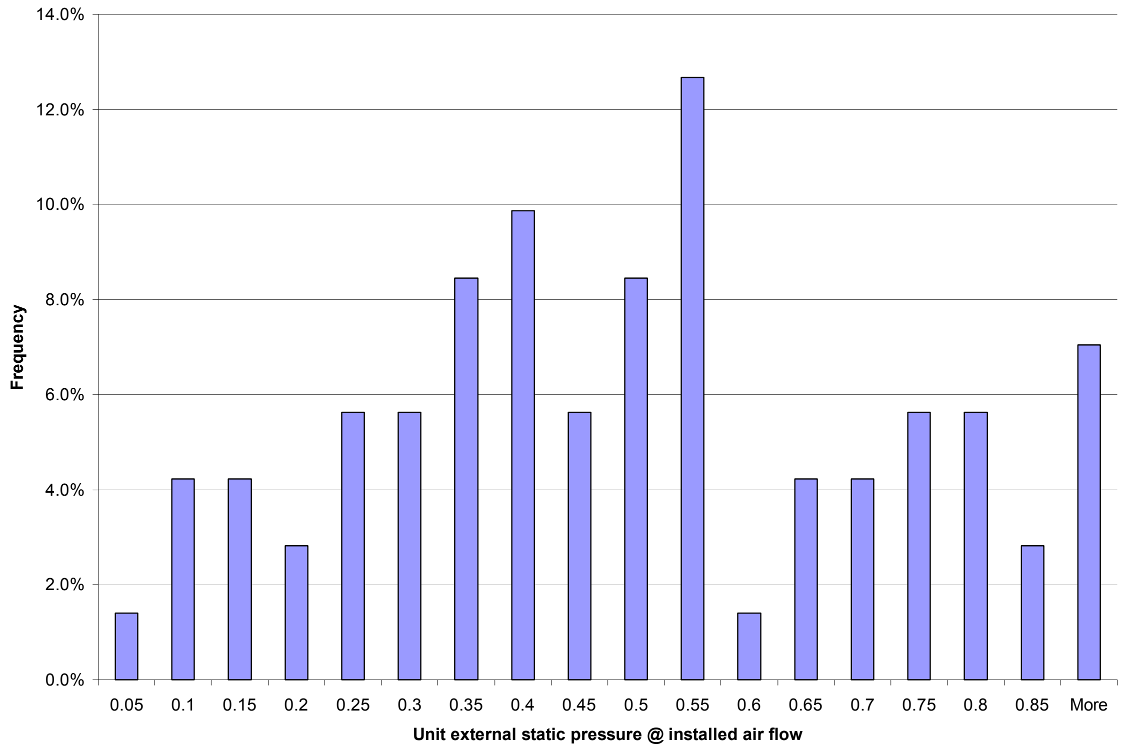

Figure 13. Distribution of Unit External Static Pressure

Thermostats

System fans were found to be cycling on and off with a call for heating or cooling in 82 (38%) of the units tested. The Title 24 Energy Standards require that all buildings not naturally ventilated with operable windows or other openings be mechanically ventilated. Mechanical ventilation is required to occur at least 55 minutes out of every hour that the building is occupied. Building outdoor ventilation air is typically supplied during fan operation, with the minimum quantity of outdoor air determined by the outdoor air damper minimum position. The supply of continuous fresh air during occupied hours relies on continuous operation of the HVAC unit supply fan. The Standards further require operation of the ventilation system at least one hour before normal building occupancy in order to purge potential build-up of pollutants and out gassing from furniture, carpets, paint, etc. Most (86%) of the thermostats surveyed were observed to be “commercial” type thermostats capable of controlling the systems according to the Title 24 and ASHRAE standards. These units can be set up to program fan schedule and mode independent of thermostat schedule.

Other Issues/Findings

A list of additional issues and findings from the field surveys and testing is summarized in Appendix A. Several of these issues are described in more detail as follows.

Duct Systems

16% of systems had ductwork running through unconditioned spaces. Of those, 60% were in unconditioned plenums; the rest were outdoors. A common building construction practice is to install a dropped ceiling in an unconditioned, high-bay warehouse to create conditioned office space. Ductwork is run from the rooftop units through a large unconditioned area to serve the offices below. This ductwork should be well-insulated and sealed against leakage to minimize duct losses to the unconditioned space. The photo below shows ductwork located in an unconditioned space, and lay-in insulation placed over the dropped ceiling tiles. Note the poor insulation coverage and the extensive use of flex duct in the distribution system.

Figure 14. Lay-in insulation and ductwork in an unconditioned space serving the conditioned office area of a high-bay unconditioned warehouse.

Several sites were also observed with ductwork running across the roof surface. Although this practice is allowed under the Title 24 Energy Standards, the ductwork should be well-insulated, weather-proofed, and sealed against duct leakage to minimize distribution system losses.

Figure 15. Ductwork located Outdoors

Unoccupied Fan Operation

Fan schedules were compared to building occupancy schedules to identify units where the fans ran during unoccupied periods. This occurred in 65 of the 215 units surveyed, or about 30% of the time.

Simultaneous Heating and Cooling

Short term monitored data collected at the round 1 sites was examined for evidence of simultaneous heating and cooling, where units serving adjacent spaces are heating and cooling at the same time, possibly "fighting" each other to maintain the control setpoint. Some evidence of this was found in 8 out of 140 (6%) units monitored in round 1.

No Outdoor Air

One of the functions of the HVAC unit is to provide continuous outside air during occupied periods. This requires an outdoor air inlet at the unit and an outdoor air damper set to allow outdoor air to enter the building when the fan is energized. A small number of units survey (9 out of 215) had either no provision for outdoor air, or the outdoor air dampers were completely closed.

Poor Maintenance Practices.

One of the casual observations made at each site was to identify and record evidence of poor maintenance practices. The following section describes a few of the issues observed during the field study.

The following photos were taken at a newly constructed restaurant soon **after** a visit by the HVAC service contractor. The roof was littered with old, filthy filters and bent and discarded “bird screens” intended to protect the unit’s outdoor air opening.

Figure 16. Poor Maintenance Practices.

A closer inspection revealed several instances of missing filters and filthy cooling coils.

Figure 17. Dirty Evaporator Coil Due to Lack of Maintenance

This fan motor fell off its mounting and into the evaporator coil. Although refrigerant wasn't lost, there was no airflow. Comfort complaints that went on for weeks were blamed on a thermostat problem. A simple check of the system would have discovered this problem much earlier.

Figure 18. Fan Motor Mount Failure

Design and Construction Faults

Several design and construction faults were also observed during the field inspections. Although these faults were isolated, they indicate a lack of inspection and/or verification of correct design and/or unit installation.

Faulty Wiring. The NEC requires a fused disconnect at the unit to allow for shutting off power during unit service. This unit was directly wired to the main panelboard, with unit connections made using wirenuts.

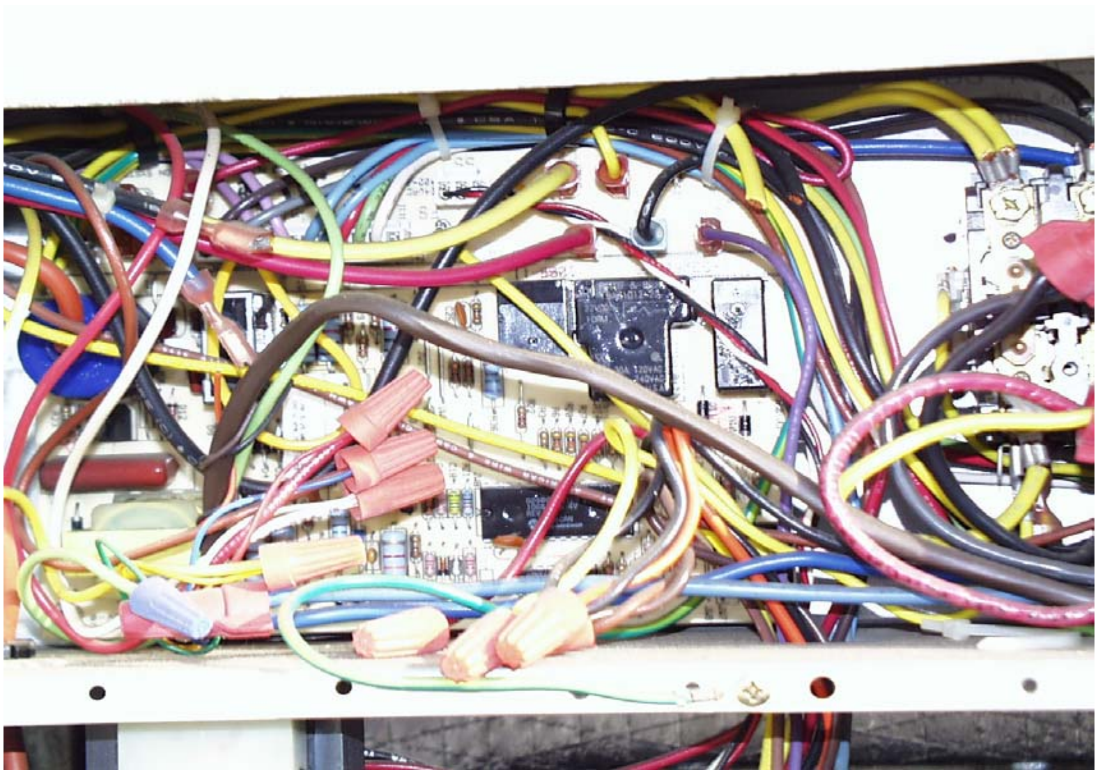

Figure 19. Poor Wiring Installation

Incompatible unit and curb design. All units observed at this site were set on an incompatible curb, where the supply and return duct connections did not line up with the unit supply and return compartments. Significant supply air bypass into the unit return was the result. The bypassed supply air reduces unit capacity and efficiency.

Figure 20. Misalignment of unit supply and return outlets with building ductwork

Figure 21. Close-up of unit supply plenum showing bypass into return side

Outdoor Air Intake Adjacent to Exhaust Fan. This toilet exhaust fan was discharging directly into the outdoor air intake of a rooftop unit. Ventilation air contamination and odor problems result from this design flaw.

Figure 22. Exhaust Fan Discharge Into Outside Air Intake

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APPENDIX A SUMMARY OF FIELD DATA

Table A-1. Sites Included in Study

SITE ID	Site Name	Building Type	City	Round
1	1956 Palma	Office	Ventura	1
5	Jack in The Box / Arco	Restaurant	Santa Rosa	1
7	1650 Northpoint	Office	Santa Rosa	1
11	IDS - Disney Dist. Offices	Office	Ontario	1
15	Albertson's	Grocery	La Mesa	1
16	Sam's Club	Retail	Stanton	1
17	Auto Zone	Retail	Barstow	1
24	Cantoni Furniture	Retail	Irvine	1
29	Otay	Retail	Chula Vista	1
37	Radiological Associates	Office	Sacramento	1
39	Sagebrush-Elderlife	Assembly	Bakersfield	1
49	Apple Valley Science and Technology Center	School	Apple Valley	1
51	Victory Outreach Church	Assembly	San Bernardino	1
53	St. Michaels Episcopal Church School	School	Carmichael	1
55	Jardiniere	Restaurant	San Francisco	1
59	Burger King	Restaurant	Roseville	1
60	Jack In the Box	Restaurant	Watsonville	1
62	Camino Real Marketplace	Retail	Irvine	1
63	Babies "R" Us	Retail	La Mesa	1
64	Kragen Auto Parts	Retail	Marysville	1
65	Michael's	Retail	San Fernando	1
67	Carl's Jr.	Restaurant	Westminster	1
77	School of Cosmotology, Handicap Ed	Office	Simi Valley	1
80	Henry J Kaiser High School	School	Fontana	1
133	Folsom High School	School	Ontario	1

SITE ID	Site Name	Building Type	City	Round
146	Safeway	Grocery	Folsom	1
147	Chevron/Food Mart	Grocery	Oakland	1
152	Wentzel and Sons Moving and Storage	Warehouse	San Fernando	1
161	Adventure Christian Church	Assembly	Roseville	1
165	Swan Market	Office	Oakland	1
166	Jewish Community Center	Assembly	San Diego	1
168	National Steinbeck Center	Assembly	Salinas AP	1
169	Monrovian Family Restaurant	Restaurant	Paramount	1
170	IHOP	Restaurant	Sacramento	2
172	Bernice Ayar Middle School	School	San Clemente	1
174	Foundation for the Retarded of the Desert	Other	Palm Desert	2
175	Huntington Seacliff Elementary School	School	Huntington Beach	1
176	US Dept of Agriculture	Office	Los Angeles	1
185	Walgreens	Retail	San Francisco	2
186	Rio Calaveras Elementary School	School	Stockton	1
195	Manufacturing Complex	Other	Buena Park	2
197	Allure	Warehouse	San Bernardino	2
198	Chevron/Food Mart	Grocery	Los Banos	2
207	Office Building	Office	San Diego	2
211	Sunsports	Warehouse	Irvine	2
213	Mediaworks	Office	Culver City	2
216	GEICO Regional HQ Building Phase II	Office	Poway Valley	2
238	Babies R Us	Retail	La Habra	1
244	Rite Aid	Retail	Apple Valley	1
245	Staples	Retail	Lancaster	2
250	American Canyon Middle School	School	Napa	1
259	Albertson's	Grocery	Union City	2
261	North Canyon Business Center	Office	Livermore	2
265	Fire Station #5	other	Sanger	2

SITE ID	Site Name	Building Type	City	Round
268	True Hope of God in Christ	Assembly	San Francisco	2
270	Kragen Auto Parts	Retail	Modesto	2
273	Playground Design	Warehouse	Vista	2
280	COSTCO	Retail	Montebello	2
283	Regenesis	Warehouse	San Clemente	2
314	Maximilian Kolbe Catholic Church	Assembly	Thousand Oaks	2
317	Soka University	School	Aliso Viejo	2
325	Valencia Commerce Center Bldg. B	Warehouse	San Fernando	2
332	Raymond	Warehouse	Ontario	2
339	In Motion Fitness	Assembly	Chico	2
340	Young NAK Presbyterian Church	Assembly	Burbank	2
343	Target	Retail	Walnut Creek	2
347	Grey Barr Electric	Warehouse	Inglewood	2
365	Budway	Office	Fontana	2
376	Home Depot	Retail	El Monte	2
388	Genica	Warehouse	Oceanside	2
402	Home Depot Distribution Center	Warehouse	Cucamonga	2
407	Albertson's	Grocery	Mountain View	2
467	Clover Springs Rec Center	Assembly	Cloverdale	2
484	Temple Baptist Church	Assembly	Lodi	2
525	Laguna Hills Senior Center	Assembly	Laguna Hills	2

Table A-2 HVAC Units Surveyed

SITE ID	Unit No.	Manufacturer	Model No.	Cooling Capacity (ton)
1	1	Carrier	48SS-06008531AA	5
1	2	Carrier	48SS-06008531AA	5
1	3	Carrier	48SS-06008631AA	5
1	4	Carrier	48SS-06008631AA	5
5	1	York	D1EG120N16525JSE	10
5	2	York	D1EG090N13025E	7.5
5	3	York	D1EG120N16525JSE	10
7	1	Bryant	582AEW048090AAAG	4
7	2	Bryant	582AEW036060AAAF	3
7	3	Bryant	582APW030060AAAD	2.5
11	1	Carrier	50TJQ005	4
11	2	Carrier	50TJQ004	3
11	3	Carrier	50TJQ004	3
11	4	Carrier	50TJQ004	3
15	1	Trane	YCD060C4LFBF	5
15	2	Trane	YCD075C4LGBE	6
15	3	Trane	YCH090DLLFBE	7.5
15	4	Trane	YCD036C4LGBE	3
16	1	Lennox	LCB120HNIG-B	10
16	2	Lennox	LCB240HNIG-B	20
16	3	Lennox	LCB240HNIG-B	20.1
16	4	Lennox	LCB240HNIG-B	20.1
17	1	Carrier	48HJ006V531CA	5
17	2	Carrier	48HJ006V531CA	5
17	3	Carrier	48HJ006V531CA	5
24	1	Carrier	50HJQ0012---601	10

SITE ID	Unit No.	Manufacturer	Model No.	Cooling Capacity (ton)
24	2	Carrier	50HJQ0012---601	10
24	3	Carrier	50HS-060---601AB	5
24	4	Carrier	50HJQ005---601	4
29	1	Rheem	RRKA-A048CK08E	4
29	2	Rheem	RRKA-A036CK06E	3
29	3	Rheem	RKKB-A090CM1SE	7.5
37	1	Trane	YCD060C4LOBF	5
37	2	Trane	YCD060C4LOBF	5
37	3	Trane	YCD048C4LOBF	5
37	4	Trane	YCD090C4LOBE	7
39	1	Trane	YCD049C3C0BF	4
39	2	Trane	YCD037C3L	3
39	3	Day & Night	581BEV060072AAAA	5
49	1	trane	YCD 075	6.5
49	2	trane	ycd 075	6.5
49	3	trane	ycc 018F	2
49	4	trane	YCC 024F	2.5
51	1	york	B3CH120A46B	10
51	2	york	B3CH120A46B	10
51	3	york	B3CH090A46A	7.5
53	1	CARRIER	48HJD006	5
53	2	CARRIER	48HJD006	5
53	3	CARRIER	48HJD007	6
53	4	CARRIER	48HJD007	6
55	1	York	D1eg090N13625E	7.5
55	2	York	d1eg09013625e	7.5
55	3	York	D1EG120N16525JSE	10
55	4	York	D1EG120N16525JSE	10

SITE ID	Unit No.	Manufacturer	Model No.	Cooling Capacity (ton)
59	1	Carrier	48HJD006---531	5
59	2	Carrier	48HJD007	6
59	3	Carrier	48HJD007---531	6
59	4	Carrier	48HJD008531	7.5
60	1	York	D1EG120N165255TF	10
60	2	York	D1EG090N13025ECF	7.5
62	1	Carrier	48HJD006---631	5
62	2	Carrier	48HJD006---631	5
62	3	Carrier	48HJD008---631	7.5
62	4	Carrier	48HJD008---631	7.5
63	1	lennox	LGA 180 SS 16	15
63	2	lennox	LGA 180SS1G	15
63	3	Lennox	LGA 180 SS 1G	15
64	1	Trane	YFD048C3LFBE	4
64	2	Trane	YFD048C3LFBE	4
64	3	Trane	YFD048C3LFBE	4
65	1	Lennox	LGA150SS2G	12
65	2	Lennox	LGA120SSIG	10
65	3	Lennox	LGA120SSIG	10
65	4	Lennox	LGA120SSIG	10
67	1	York	D1EG090N13025	7.5
67	2	York	D1EG180N24025ECE	15
77	1	Carrier	48HJD006	5
77	2	Carrier	48HJD007	6
80	1	Carrier	48HJD008-631	7.5
80	2	Carrier	48HJD008631	7.5
80	3	Carrier	48HJD005631	4
80	4	Carrier	48HJD005631	4

SITE ID	Unit No.	Manufacturer	Model No.	Cooling Capacity (ton)
133	1	BDP	581BEX060072	5
133	2	BDP	581BEX060072	5
133	3	BDP	581BEX060072	5
133	4	BDP	581BEX060072	5
146	1	Carrier	48HJE006	5.1
146	2	Carrier	48HJE004	3
146	3	Carrier	48HJE004	3
147	1	York	B3CH090-A25STB	7.5
147	2	York	B3CH036-A258D	7.53
152	1	Rheem	RPDC-075DLA	6
152	2	Rheem	RQKA-OAO24JK	1.9333
161	1	YORK	D1N036N03646C	3
161	2	YORK	D1NA036N03646C	3
161	3	YORK	D1NA042N05646C	3.5
161	4	YORK	D1NA060N06546C	5
165	1	Carrier	48TJD008---5216A	7.5
165	2	Carrier	48TJD007--521	6
165	3	Carrier	48TJD014---5316A	12.5
165	4	Carrier	48TJD014---5316A	12.5
166	1	Carrier	48HJD008-C631	7.5
166	2	Carrier	48HJD006	5
166	3	Carrier	48HJD005	4
166	4	Carrier	48HJD007	6
168	1	Trane	YCH121C4L	10
168	2	Trane	YCD103C4L	8.5
168	3	Trane	YCH103C4L	8.5
168	4	Trane	YCH103C4L	8.5
169	1	Carrier	48TJD007---501--	6

SITE ID	Unit No.	Manufacturer	Model No.	Cooling Capacity (ton)
169	2	Carrier	48HJD007---531--	6
170	1	York	D1EG090N13025ECE	7.5
170	2	York	D2EG048N06025	4
170	3	York	D1EG090N13025ECE	7.5
172	1	Trane	YCD103C4LBAA	8.5
172	2	Trane	YCD049C4LBBE	4
172	3	Trane	YCD049C4LBBE	4
172	4	Trane	YCC024F1LOBE	2
174	1	Trane	YCD091D4LOBE	7.5
174	2	Trane	YCD091D4LOBE	7.5
175	1	Trane	YCH 103C4LPA3	8.5
175	2	trane	YCD 061 C4 LCBI	5
175	3	Trane	YCD 091 D4 L6Be	7
176	1	Carrier	50TJQ004-501GA	3
176	2	Carrier	50HS-024-311AB	2
176	3	Carrier	50TJQ004-501GA	3
176	4	Carrier	50HS-018-301AB	1.5
185	1	Trane	YCD091D4LABE	7.5
185	2	Trane	YCD091D4LABE	7.5
185	3	Trane	YCD091D4LABE	7.5
185	4	Trane	YCD061C4LABF	5
186	1	Trane	YCD049C4LCBE	4.125
186	2	Trane	YCD049C4LCBE	4.125
186	3	Trane	YCD049C4LCBE	4.125
186	4	Trane	YCD074C4LCBE	5.67
195	1	York	B1HA024A06B	2
195	2	York	B1HA024A06B	2
195	3	York	B1HA024A06B	2

SITE ID	Unit No.	Manufacturer	Model No.	Cooling Capacity (ton)
197	1	Carrier	50TJQ004---601GA	3
197	2	Carrier	50TJQ004---601GA	3
197	3	Carrier	50TJQ006-601GA	5
197	4	Carrier	50TJQ006---601GA	5
198	1	Bryant	501BPU031072APAA	3
198	2	Bryant	581PU060072ADAA	5
207	1	Carrier	50TJQ005	4
207	2	Carrier	50TJQ005	4
211	1	Trane	WCD090C400BC	7.5
211	2	Can't Read	Can't Read	
213	1	Lennox	LGA120SH19	10
216	1	Carrier	50TJQ006	5
238	1	Lennox	LGA180HSIG	15.67
238	2	Lennox	LGA180HSIG	15.7
238	3	Lennox	LGA180HSIG	15.67
238	4	Lennox	LGA180HSIG	15
244	1	York	D2EG150N20025EAD	12
244	2	York	D2EG150N20025EAD	12
244	3	York	D2EG150N20025EAD	12
244	4	York	D2EG150N20025EAD	12
245	1	Carrier	48DJB012530	10
245	2	Carrier	48DJD008530	7.5
245	3	Carrier	48LJE006520	5
250	1	CARRIER	48HJD007	6
250	2	CARRIER	48HJD008	7.5
250	3	CARRIER	48HJD006	5
250	4	CARRIER	48HJD008	7.5
259	1	Trane	YCD036C4LGBE	3

SITE ID	Unit No.	Manufacturer	Model No.	Cooling Capacity (ton)
259	2	Trane	YCD036C4LGBE	3
259	3	Trane	YCD060C4LC13F	5
261	1	Bryant	580DEV120180ACAA	10
261	2	Bryant	580DEU120180ACAA	10
265	1	York	D2CG072N0792SEBA	6
265	2	York	D7CG060N07925DBA	5
268	1	Trane	YCD06DC3LOBT	5
268	2	Carrier	48TJF008	7.5
270	1	Trane	YSC036A3RLA01D0012A	3
270	2	Trane	YSC036A3RLA01D0012A	3
270	3	Trane	YSC036A3RLA01D0012A	3
273	1	Trane	WC0048F400BF	4
273	2	Trane	WCCO48F400BF	4
280	1	Carrier	50NQ030321	2.5
280	2	Carrier	50NQ024-311	2
283	1	Carrier	50TJQ006	5
283	2	Carrier	50TJQ005	4
283	3	Carrier	50TJQ004	3
314	1	Carrier	50SX-042-601-AA	3.5
317	1	Trane	WCH1508400EA	12.5
325	1	Carrier	5DTJQ006-601GA	5
332	1	Carrier	50JS-036-601	3
332	2	Carrier	50JS-036-601	3
339	1	Carrier	48HJD008	7.5
340	1	Carrier	50JTJQ012-501GA	10
340	2	Carrier	50TJQ005-501GA	4
343	1	Aaon	RR08-3-PO-212	8
343	2	Aaon	RK063E0222	6

SITE ID	Unit No.	Manufacturer	Model No.	Cooling Capacity (ton)
347	1	Trane	YFD075C4LCBE	6.25
365	1	Carrier	50HS-024031146	2
365	2	Carrier	50HS-0240311AB	2
376	1	Carrier	48HJD006---631--	5
376	2	Carrier	48HJE004---631	3
388	1	ICP	PHF060L000A	5
388	2	ICP	PHF060L00A	5
402	1	Rheem	RJKA-A048DM	4
402	2	Rheem	RJKA-A060DM	5
407	1	Trane	YCD036C4LGBE	3
407	2	Trane	YCD036C4LGBE	3
467	1	York	D3CG120N16525D	10
467	2	York	D7CG048N06025A	4
467	3	York	D3C6120N16525D	10
467	4	York	D2C6072N07925A	6
484	1	Trane	YCD074C4CABE	6.25
484	2	Trane	YCD121C4LAAA	10
525	1	Carrier	48TJD007-521	6
525	2	Carrier	48TJD007-521	6

Table A-3 Economizer Data

SITE ID	Unit No.	Linkage Moves	Responds to Cold Air	Monitoring shows modulation	Economizer works	Control type	Changeover Setpoint
5	1	Yes	No	No	No	Delta T	
5	2	Yes		Yes	Yes	Single T	
5	3	Yes		Yes	Yes	Delta T	
15	1	No		No	No	Single T	A
15	2	No		No	No	Single h	A
15	3	Yes	Yes	No	No	Single T	A
15	4	Yes	No	No	No	Single h	A
24	1			No	No	Delta h	
24	2			No	No	Delta h	
24	4			No	No	Delta h	
29	1	No		No	No	Single h	A
29	2	Yes		No	No	Single h	A
29	3	No		No	No	Single T	B
37	1	Yes	Yes	Yes	Yes	Delta T	
37	2	Yes	Yes	Yes	Yes	Delta T	
37	3	Yes	Yes	No	No	Delta T	
37	4	Yes	Yes	No	No	Delta T	
39	1	Yes	No	No	No	Delta T	
39	2	Yes	No	No	No	Delta T	
49	1	No		No	No	Delta T	
49	2	No		No	No	Delta T	
51	1	No		No	No	Single T	
51	2	No		No	No	Single T	
51	3	Yes	Yes	Yes	Yes	Single T	
53	1	Yes		Yes	Yes	Delta h	
53	2	Yes		Yes	Yes	Delta h	

SITE ID	Unit No.	Linkage Moves	Responds to Cold Air	Monitoring shows modulation	Economizer works	Control type	Changeover Setpoint
53	3	Yes		Yes	Yes	Delta h	
53	4	Yes		No	No	Delta h	
55	1			No	No	Delta h	
55	2			No	No	Delta h	
55	3			No	No	Delta h	
55	4			No	No	Delta h	
60	1			No	No	Delta h	
60	2			No	No	Delta h	
62	3	Yes		Yes	Yes	Delta h	
62	4	Yes		Yes	Yes	Delta h	
63	1	No		No	No	Delta h	
63	2	No		No	No	Delta h	
63	3	No		No	No	Delta h	
65	1	No		No	No	Delta h	
65	2	No		No	No	Delta h	
65	3	No		No	No	Delta h	
65	4	No		No	No	Delta h	
67	1	Yes	Yes	Yes	Yes	Single h	D
67	2	Yes	Yes	Yes	Yes	Single h	D
77	1	No		No	No	Single h	D
77	2	No		No	No	Single h	D
80	1	Yes	No	No	No	Single T	
80	2	Yes	No	No	No	Single T	
80	3	Yes	No	No	No	Single T	
80	4	Yes	No	No	No	Single T	
133	1	Yes	No	No	No	Delta h	
133	2	Yes		No	No	Delta h	

SITE ID	Unit No.	Linkage Moves	Responds to Cold Air	Monitoring shows modulation	Economizer works	Control type	Changeover Setpoint
133	3	Yes		No	No	Delta h	
133	4	Yes	No	No	No	Delta h	
146	1	No		No	No	Delta h	
146	2	Yes	Yes	Yes	Yes	Delta h	
146	3	Yes	Yes	No	No	Delta h	
147	1	Yes		Yes	Yes	Single h	A
147	2	Yes		Yes	Yes	Single h	B
165	1	Yes	No	No	No	Single h	C
165	2	Yes	No	No	No	Single h	B
165	3	Yes	No	No	No	Single h	B
165	4	Yes	Yes	Yes	Yes	Single h	C
166	1	Yes	Yes	Yes	Yes	Single h	C
168	1	Yes		Yes	Yes	Delta T	
168	2	No		No	No	Delta T	
168	3	Yes		No	No	Delta T	
168	4	Yes		Yes	Yes	Delta T	
170	1	No			No	Single h	A
170	2	Yes	No		No	Single h	A
170	3	No			No	Single h	
172	1	Yes	Yes	Yes	Yes	Single T	A
172	2	Yes	Yes	No	No	Single T	A
172	3	Yes	Yes	No	No	Single T	A
172	4	Yes	Yes	No	No	Single T	A
174	1	Yes	Yes		Yes	Single T	A
174	2	Yes	Yes		Yes	Single T	A
175	1	No		No	No	Single T	
185	1	Yes	Yes		Yes	Delta h	

SITE ID	Unit No.	Linkage Moves	Responds to Cold Air	Monitoring shows modulation	Economizer works	Control type	Changeover Setpoint
185	2	Yes	No		No	Delta h	
185	3	Yes	Yes		Yes	Delta h	
185	4	Yes	Yes		Yes	Delta h	
186	1	Yes		Yes	Yes	Delta T	
186	2	Yes		No	No	Delta T	
186	3	Yes		No	No	Delta T	
186	4	Yes		No	No	Delta T	
216	1	Yes	No		No	Delta h	
238	1	Yes		Yes	Yes	Delta h	
238	2	Yes		Yes	Yes	Delta h	
238	3	Yes		Yes	Yes	Delta h	
238	4	Yes		Yes	Yes	Delta h	
244	1	Yes	Yes	No	No	Single h	D
244	2	Yes	Yes	No	No	Single h	D
244	3	Yes	Yes	No	No	Single h	D
244	4	Yes	Yes	No	No	Single h	D
245	1	Yes	Yes		Yes	Single h	C
245	2	No			No	Delta h	
259	1	No			No	Delta h	
259	2	Yes	Yes		Yes	Delta h	
259	3	Yes	Yes		Yes	Delta h	
261	1	Yes	No		No	Delta h	
261	2	No			No	Delta h	
265	1	Yes	No		No	Single h	C
265	2	Yes	Yes		Yes	Delta h	
268	1	Yes	No		No	Single T	A
268	2	Yes	Yes		Yes	Single h	D

SITE ID	Unit No.	Linkage Moves	Responds to Cold Air	Monitoring shows modulation	Economizer works	Control type	Changeover Setpoint
270	1	Yes			Yes	Single T	D
270	2	Yes			Yes	Single T	D
270	3	Yes			Yes	Single T	D
280	1	No			No	Delta h	
280	2	No			No	Delta h	
317	1	Yes	No		No	Single T	A
339	1	Yes	Yes		Yes	Single h	D
340	1	No			No	Single T	B
343	1	Yes	Yes		Yes	Single T	
343	2	Yes	Yes		Yes	Single T	
376	1	Yes	No		No	Single T	
376	2	No			No	Single T	C
407	1	No			No	Delta h	
407	2	Yes	Yes		Yes	Delta h	
484	1	Yes			Yes	Delta T	
484	2	Yes			Yes	Delta T	

Table A-4. Air Flow and Fan Power Test Results

SITE ID	Unit no.	Capacity (ton)	Measured CFM	Cfm/ton	Deviation from 400 cfm/ton	EER impact
170	AC-1	7.5	684	91	-77%	-27%
170	RTU-2	4	1,010	253	-37%	-13%
170	RTU-3	7.5	1,850	247	-38%	-13%
174	AC-1	7.5	1,935	258	-36%	-12%
174	AC-2	7.5	2,017	269	-33%	-11%
185	AC-3	7.5	2,890	385	-4%	-1%
185	AC-4	7.5	2,704	361	-10%	-3%
185	AC-5	5	1,977	395	-1%	0%
195	AC2	2	707	354	-12%	-4%
195	AC3	2	650	325	-19%	-7%
195	AC4	2	1,065	533	33%	12%
197	RTU#1	5	1,190	238	-41%	-14%
197	Unit #3	3	924	308	-23%	-8%
197	Unit #4	3	990	330	-18%	-6%
197	Unit#2	5	1,290	258	-36%	-12%
198	AC1	3	872	291	-27%	-10%
198	AC2	5	1,307	261	-35%	-12%
207	AC-1	4	1,840	460	15%	5%
207	AC-2	4	1,495	374	-7%	-2%
211	AC-1	7.5	2,076	277	-31%	-11%
211	AC-3	4	1,364	341	-15%	-5%
213	AC30	10	3,117	312	-22%	-8%
216	RTU-09	5	1,437	287	-28%	-10%
245	AC12	7.5	2,565	342	-15%	-5%
259	RTU-1	5	1,702	340	-15%	-5%
259	RTU-2	3	820	273	-32%	-11%

SITE ID	Unit no.	Capacity (ton)	Measured CFM	Cfm/ton	Deviation from 400 cfm/ton	EER impact
259	RTU-3	3	960	320	-20%	-7%
261	AC-1	10	3,611	361	-10%	-3%
261	AC-2	10	3,310	331	-17%	-6%
265	AC-1	5	1,626	325	-19%	-7%
265	AC-2	6	1,173	196	-51%	-18%
268	AC-1	5	1,870	374	-7%	-2%
268	RTU-2	7.5	1,650	220	-45%	-16%
270	AC-1	3	1,445	482	20%	7%
270	AC-2	3	1,360	453	13%	5%
270	AC-3	3	1,350	450	13%	4%
273	A/C South	4	1,330	333	-17%	-6%
273	N1	4	1,390	348	-13%	-5%
280	AC2	2	872	436	9%	3%
280	AC4	2.5	1,021	408	2%	1%
283	AC-1.1	4	1,210	303	-24%	-9%
283	AC-1.2	3	860	287	-28%	-10%
283	AC-1.6	5	1,020	204	-49%	-17%
314	AC-7	3.5	790	226	-44%	-15%
317	AC1	12.5	3,632	291	-27%	-10%
325	RTU-1	5	1,480	296	-26%	-9%
332	E-2	3	960	320	-20%	-7%
332	East 1	3	950	317	-21%	-7%
339	AC-11	7.5	2,399	320	-20%	-7%
340	RTU-3	10	3,760	376	-6%	-2%
340	Unit 1	4	1,300	325	-19%	-7%
343	RTU-1	6	2,403	401	0%	0%
343	RTU-5	8	3,991	499	25%	9%
347	RTU-4	6.25	2,590	414	4%	1%

SITE ID	Unit no.	Capacity (ton)	Measured CFM	Cfm/ton	Deviation from 400 cfm/ton	EER impact
365	Unit 1	2	935	468	17%	6%
365	Unit 2	2	690	345	-14%	-5%
376	Unit 2	3	789	263	-34%	-12%
376	Unit1	5	982	196	-51%	-18%
388	Unit-1	5	1,550	310	-23%	-8%
388	Unit-2	5	1,395	279	-30%	-11%
402	RTU-1	4	1,935	484	21%	7%
402	RTU-2	5	1,705	341	-15%	-5%
407	AC-1	3	1,222	407	2%	1%
407	AC-2	3	1,059	353	-12%	-4%
467	AC-1	10	2,667	267	-33%	-12%
467	AC-2	10	2,903	290	-27%	-10%
467	AC-3	6	1,044	174	-57%	-20%
467	AC-4	4	1,163	291	-27%	-10%
484	A6-10	6.25	2,030	325	-19%	-7%
484	AC-11	10	3,390	339	-15%	-5%
525	#2	6	1,170	195	-51%	-18%
525	RTU-1	6	1,500	250	-38%	-13%

Table A-5. Fan Power Normalized to Nominal Capacity

Site ID	Unit #	Cooling Capacity	Supply Fan Power/ Ton (kW)
1	1	5	0.16
1	2	5	0.16
1	3	5	0.12
1	4	5	0.12
5	3	10	0.26
7	1	4	0.15
7	2	3	0.05
7	3	2.5	0.05
11	1	4	0.14
11	2	3	0.16
11	3	3	0.16
11	4	3	0.15
15	1	5	0.13
15	2	6	0.12
15	3	7.5	0.16
15	4	3	0.22
17	1	5	0.09
17	2	5	0.27
17	3	5	0.12
29	1	4	0.09
29	2	3	0.33
29	3	7.5	0.03
37	1	5	0.16
37	2	5	0.17
37	3	5	0.20
37	4	7	0.18
39	1	4	0.08

Site ID	Unit #	Cooling Capacity	Supply Fan Power/ Ton (kW)
39	2	3	0.02
39	3		0.20
49	1	6.5	0.09
49	2	6.5	0.14
49	3	2	0.07
49	4	2.5	0.14
51	1	10	0.14
51	2	10	0.79
51	3	7.5	0.48
53	1	5	0.28
53	2	5	0.08
53	3	6.5	0.21
53	4	6.5	0.21
55	1	7.5	0.13
55	2	7.5	0.10
55	3	10	0.26
55	4	10	0.20
60	1	10	0.18
60	2	7.5	0.18
62	1	5	0.15
62	2	5	0.11
62	3	7.5	0.29
62	4	7.5	0.25
63	1	15	0.18
63	2	15	0.17
63	3	15	0.14
64	1	4	0.12
64	2	4	0.18

Site ID	Unit #	Cooling Capacity	Supply Fan Power/ Ton (kW)
64	3	4	0.13
65	1	12	0.18
65	2	10	0.19
65	3	10	0.28
65	4	10	0.13
67	1	7.5	0.39
67	2	15	0.39
77	1	5	0.17
77	2	6	0.24
80	1	7	0.23
80	2	7	0.15
80	3	4	0.22
80	4	4	0.22
133	1	5	0.16
133	2	5	0.14
133	3	5	0.20
133	4	5	0.19
146	1	5.1	0.67
146	2	3	0.22
146	3	3	0.28
147	1	7.5	0.65
147	2	7.53	0.70
152	1	7.5	0.11
161	1	3	0.22
161	2	3	0.37
161	3	3.5	0.15
161	4	5	0.17
166	1	7.5	0.39

Site ID	Unit #	Cooling Capacity	Supply Fan Power/ Ton (kW)
166	2	5	0.09
166	3	4	0.20
166	4	6	0.29
168	1	10	0.14
168	2	8.5	0.15
168	3	8.5	0.13
168	4	8.5	0.22
170	AC-1	7.5	0.05
170	RTU-2	4	0.00
172	1	8.5	0.14
172	2	4	0.27
172	3	4	0.26
172	4	2	0.11
174	AC-1	7.5	0.09
174	AC-2	7.5	0.12
175	1	8.5	0.21
175	2	5	0.14
175	3	7	0.11
176	1	3	0.04
176	2	2	0.02
176	3	3	0.04
176	4	1.5	0.02
185	AC-1	7.5	0.19
185	AC-3	7.5	0.19
185	AC-4	7.5	0.18
185	AC-5	5	0.15
186	1	4.125	0.26
186	2	4.125	0.30

Site ID	Unit #	Cooling Capacity	Supply Fan Power/ Ton (kW)
186	3	4.125	0.19
186	4	5.67	0.20
195	AC2	2	0.12
195	AC3	2	0.12
195	AC4	2	0.21
197	RTU#1	5	0.11
197	Unit #3	3	0.13
197	Unit #4	3	0.15
197	Unit#2	5	0.13
198	AC1	3	0.13
198	AC2	5	0.15
207	AC-1	4	0.22
207	AC-2	4	0.16
211	AC-1	7.5	0.10
211	AC-3	4	0.18
213	AC30	10	0.16
216	RTU-09	5	0.13
238	1	15.67	0.20
238	2	15.7	0.21
238	3	15.67	0.30
238	4	15	0.24
244	2	12	0.17
244	3	12	0.17
244	4	12	0.16
245	AC12	7.5	0.19
250	1	6	0.28
250	2	7.5	0.22
250	3	5	0.25

Site ID	Unit #	Cooling Capacity	Supply Fan Power/ Ton (kW)
250	4	7.5	0.19
259	RTU-1	5	0.20
259	RTU-2	3	0.11
259	RTU-3	3	0.10
265	AC-1	5	0.18
265	AC-2	6	0.09
268	AC-1	5	0.15
268	RTU-2	7.5	0.20
270	AC-1	3	0.09
270	AC-2	3	0.12
270	AC-3	3	0.15
273	A/C South	4	0.16
273	N1	4	0.29
280	AC2	2	0.18
280	AC4	2.5	0.16
283	AC-1.1	4	0.11
283	AC-1.2	3	0.12
283	AC-1.6	5	0.09
314	AC-7	3.5	0.12
317	AC1	12.5	0.13
325	RTU-1	5	0.15
332	E-2	3	0.20
332	East 1	3	0.20
339	AC-11	7.5	0.20
340	RTU-3	10	0.19
340	Unit 1	4	0.13
343	RTU-1	6	0.27
343	RTU-5	8	0.16

Site ID	Unit #	Cooling Capacity	Supply Fan Power/ Ton (kW)
365	Unit 1	2	0.18
365	Unit 2	2	0.16
376	Unit 2	3	0.15
376	Unit1	5	0.11
388	Unit-1	5	0.16
388	Unit-2	5	0.13
402	RTU-1	4	0.24
402	RTU-2	5	0.15
407	AC-1	3	0.15
407	AC-2	3	0.11
467	AC-1	10	0.16
467	AC-2	10	0.18
467	AC-3	6	0.13
467	AC-4	4	0.16
484	A6-10	6.25	0.14
484	AC-11	10	0.16
525	#2	6	0.09
525	RTU-1	6	0.15
Average			0.18

Table A-6. Refrigerant Charge Test Results

Site ID	Unit no.	Compressor	Charge deviation (negative means undercharged)
170	AC-1	C1	0.0%
170	AC-1	C2	0.0%
170	RTU-2	C1	0.0%
170	RTU-3	C1	< - 20%
174	AC-1	C1	0.0%
174	AC-1	C2	0.0%
174	AC-2	C1	0.0%
174	AC-2	C2	0.0%
185	AC-1	C1	0.0%
185	AC-1	C2	-4.9%
185	AC-3	C1	0.0%
185	AC-3	C2	-3.9%
185	AC-4	C1	0.0%
185	AC-4	C2	9.8%
185	AC-5	C1	0.0%
195	AC2	C1	9.4%
195	AC3	C1	< - 20%
195	AC4	C1	0.0%
198	AC1	C1	0.0%
198	AC2	C1	0.0%
207	AC-1	C1	-9.6%
207	AC-2	C1	-9.6%
211	AC-1	C1	4.4%
211	AC-3	C1	-7.3%
213	AC30	C1	17.8%
213	AC30	C2	6.6%

Site ID	Unit no.	Compressor	Charge deviation (negative means undercharged)
216	RTU-09	C1	-4.7%
245	AC12	C1	0.0%
245	AC12	C2	< - 20%
259	RTU-1	C1	0.0%
259	RTU-2	C1	0.0%
259	RTU-3	C1	0.0%
261	AC-2	C1	0.0%
261	AC-2	C2	0.0%
265	AC-1	C1	0.0%
265	AC-2	C1	0.0%
268	AC-1	C1	0.0%
268	RTU-2	C1	0.0%
268	RTU-2	C2	-2.5%
270	AC-1	C1	-7.8%
270	AC-2	C1	0.0%
270	AC-3	C1	-3.1%
273	A/C South	C1	0.0%
273	N1	C1	0.0%
280	AC2	C1	-7.5%
280	AC4	C1	-7.3%
283	AC-1.1	C1	-10.6%
283	AC-1.2	C1	-9.8%
283	AC-1.6	C1	0.0%
314	AC-7	C1	0.0%
317	AC1	C1	0.0%
317	AC1	C2	0.0%
325	RTU-1	C1	-5.5%
332	E-2	C1	-1.8%

Site ID	Unit no.	Compressor	Charge deviation (negative means undercharged)
339	AC-11	C1	-26.2%
339	AC-11	C2	-12.3%
340	RTU-3	C1	-5.5%
340	RTU-3	C2	-6.3%
340	Unit 1	C1	-10.6%
343	RTU-1	C1	0.0%
343	RTU-5	C1	0.0%
347	RTU-4	C1	0.0%
365	Unit 1	C1	-20.9%
365	Unit 2	C1	4.5%
376	Unit 2	C1	-2.3%
376	Unit1	C1	0.0%
388	Unit-1	C1	19.9%
402	RTU-1	C1	22.7%
402	RTU-2	C1	34.8%
407	AC-1	C1	-5.7%
407	AC-2	C1	0.0%
467	AC-1	C1	< - 20%
467	AC-2	C1	< - 20%
467	AC-3	C1	< - 20%
467	AC-4	C1	0.0%
484	A6-10	C1	0.0%
484	AC-11	C1	0.0%
484	AC-11	C2	-5.5%
525	RTU-1	C1	-4.2%

Table A-7. Operations, Maintenance and Construction Issues

Site ID	Issue
1	There was no outside air inlet installed on one unit. The outside air dampers on the other three units were set to zero percent outside air.
5	Dirty filters indicating lack of maintenance
7	Two units were inoperable
15	Dirty filters indicating lack of maintenance
16	Dirty filters indicating lack of maintenance
17	Thermostats for three units serving same space are located together on one wall. Only one unit operates due to inconsistent setpoints or calibration problems.
29	Thermostat located in an area that has a lower cooling load than the rest of the space; other areas are under cooled. Simultaneous heating and cooling observed.
29	One of the compressors in RTU-2 is not operating, and the evaporator coil in RTU-1 is covered with ice.
37	One unit inoperable
49	Thermostat location outside of spaces served by units.
51	Dirty filters indicating lack of maintenance. The exterior panels on some of the units were not properly attached.
55	Simultaneous heating and cooling observed.
59	High supply air temperatures and low delta T indicating potential charge problem
60	Dirty filters indicating lack of maintenance
62	Dirty filters indicating lack of maintenance
63	One unit inoperable
65	One unit inoperable
67	Filters are clogged with dirt from the kitchen exhaust. Rust buildup on economizer dampers. Ice buildup on the evaporator of one of the units
133	One unit inoperable
146	Simultaneous heating and cooling observed.
147	Simultaneous heating and cooling observed.
161	High supply air temperatures and low delta T indicating potential charge problem

Site ID	Issue
165	Dirty filters indicating lack of maintenance
169	Maintenance access panels were welded on. The wiring of one of the units was unsafe because of poor installation.
170	Dirty iced coils, loose fan belt, no vibration dampers on replaced compressor, OA intake near exhaust
174	Restricted maintenance access due to parapet wall
175	High supply air temperatures and low delta T indicating potential charge problem
185	Bad schrader valve on compressor leaking refrigerant.
198	Units provide no outside air
213	Units provide no outside air
250	Units connected to wrong zones due to mislabeling.
270	Units provide no outside air

APPENDX B - SITE FINDINGS

This Appendix summarizes the results of the field testing for each site in the study. The sites in Round 1 (Summer/Fall 2001) are described first, followed by the sites in Round 2 (Summer/Fall 2002). The site conditions are described, along with an estimate of the energy impacts of the conditions observed.

1 ROUND ONE SITES

The results of the site inspections in Round 1 are described in this section. The diagnostic testing process used in Round 1 included on-site auditing, spot-testing of equipment, and short-term monitoring using battery-powered dataloggers.

During the on-site audit, a sample of HVAC units was selected for study. Information on the energy use characteristics of the spaces served by the selected units was collected, including wall and roof areas and insulation levels, window type and size, electric lighting systems and controls and miscellaneous plug loads. Building personnel were interviewed to obtain an understanding of existing O&M procedures.

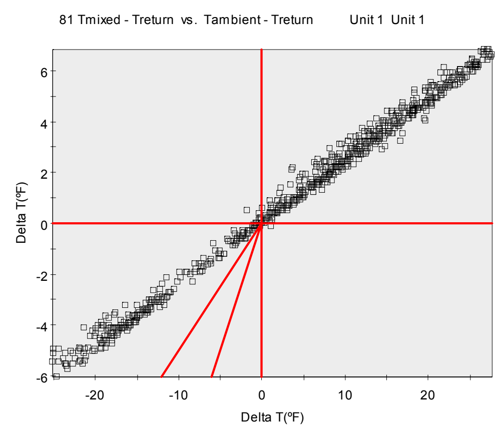
Spot-checking equipment with hand-held instruments was done to provide a glimpse of the system performance during the survey. Fan power, compressor power and economizer functional testing was conducted. The economizer functional tests consisted of a mechanical check of the dampers and actuators, followed by a cold spray test to observe the functioning of the economizer controller and sensors.

Short-term dynamic diagnostic monitoring was utilized to develop an in-depth understanding of the rooftop system operation. Short-term diagnostic testing is the application of specialized software and hardware tools to gather and analyze data for the evaluation of the performance of building energy systems. A maximum of four rooftop units were monitored at each site. Portable, battery-powered dataloggers were used to collect the following data:

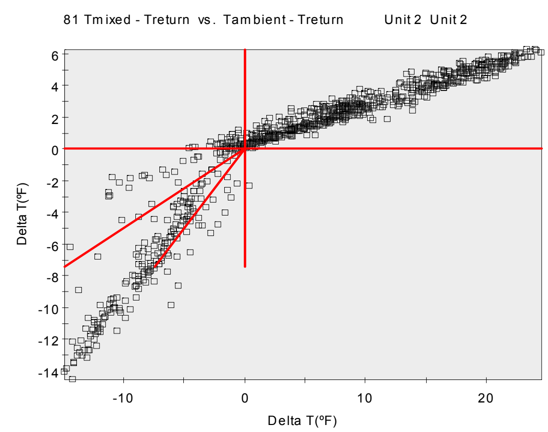
- Ambient temperature
- Relative humidity on selected sites
- Rooftop unit current
- Return air temperature
- Supply air temperature
- Mixed air temperature
- Room temperature

Data were collected every three minutes for approximately fourteen days. At the end of the monitoring period, the dataloggers were removed and the data were downloaded and analyzed. Time series plots of unit kW were used to look at fan power, fan control, and compressor operation. Diagnostic plots of temperatures were used to observe economizer operation, supply temperatures and cooling coil temperature drop under various load scenarios. Economizer diagnostic plots were used to determine if the economizers were responding properly over a range of operating conditions. Supply temperature and coil temperature drop were used to screen units for potential refrigerant charge and/or air flow problems.

An example economizer diagnostic plot is shown below. To observe economizer operation, the difference between the cooling coil entering (i.e. mixed) air temperature and the return air temperature (Tmix – Treturn) on the vertical (Y) axis is plotted against the difference between the outdoor (ambient) temperature and the return air temperature on the horizontal (X) axis. The slope of the line is equal to the outdoor air fraction. Units with fixed outdoor air (no economizer) have a straight line relationship between these data, as shown in the chart on the left. Units with functioning economizers show a characteristic change in the slope of the line to the left of the vertical (Y) axis, as shown in the chart on the right. The slope in this region is equal to one, indicating a functioning dry bulb economizer allowing 100% outdoor air.



Non-functioning economizer



Functioning Economizer

Site 1 - 1956 Palma Office Building

The Office at 1956 Palma is approximately18,500 square foot in size. The space divided between conditioned offices and unconditioned storage.

Heating and cooling for the building is provided by five-ton Carrier packaged air conditioners. None of the units are equipped with economizers. Honeywell thermostats are used to control space temperatures.

Monitoring Configuration

Short term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 1997G10051, 3497G10023, 2398g10044, and 3098G10041.

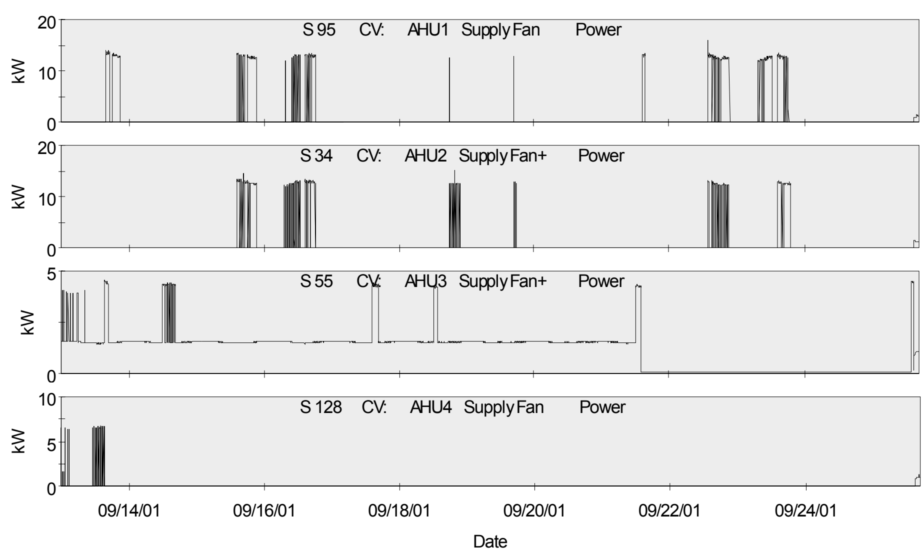
Economizer Operation

None of the units surveyed had economizers.

Fan Schedules

The supply fan in unit 2398g10044 remained on during the entire monitoring period.

Unit power vs. time



Fan Operation

The supply fan in units 1997G10051, 3497G10023, and 3098G10041 cycled with calls for cooling. The supply fan in all of the units should remain on during the occupied period to provide outside air to the space.

Fan Power

ARI ratings are based on a supply fan power of 365W/1000 cfm. On site testing showed an average of 355W/1000 cfm for the three units monitored.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition.

Other Issues

There was no outside air inlet installed on unit 2398g10044. The outside air dampers on the other three units were set to zero percent outside air.

Site 5 - Jack In the Box Rancho Cordova

The Jack In the Box at 9680 Business Park Road in Sacramento is a 4,596 square foot building. The space is conditioned and used as a quick service restaurant. Heating and cooling for the building is provided by York packaged air conditioners. All of the units are equipped with either differential temperature or single point temperature economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short term diagnostic monitoring was performed on three of the units at this site. The units are classified by the following numbers: AC-2, AC-1 and AC-3. AC-2 and AC-3 are ten ton units equipped with differential temperature economizers. AC-2 is seven and one-half tons and has a single-point temperature economizer.

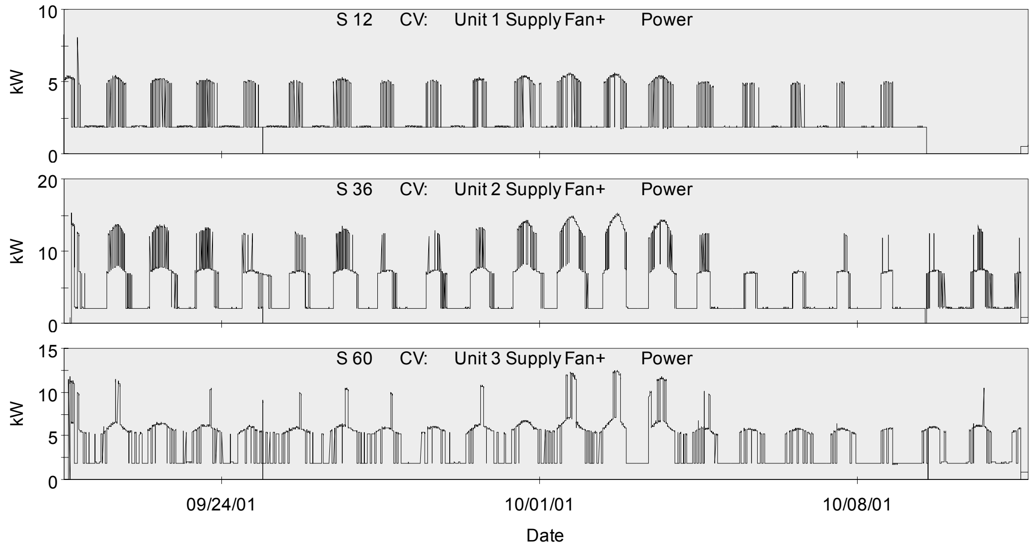
Economizer Operations

The results of diagnostic monitoring show that the economizer dampers in AC-1 did not modulate during the monitoring period. The economizer in AC-2 and AC-3 responded appropriately to changes in climatic conditions.

Fan Schedules

The supply fans in all of the units ran continuously during the monitoring period. In order to maintain a good indoor air quality it is necessary for the supply fans to remain on while the building is occupied. If portions of the building are unoccupied during portions of the evening and night the units should be scheduled off.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in adequate condition. It appears that the units have been regularly serviced and maintained, although the filters in the units were rather dirty.

Site 7 - Northpoint Offices

The Office at 1650 Northpoint Parkway in Santa Rosa is a 7,137 square foot building. The entire space is conditioned and used for offices.

Heating and cooling for the building is provided by Bryant packaged air conditioners. None of the units are equipped with economizers, which modulate outside air proportions and provide free cooling when conditions permit.

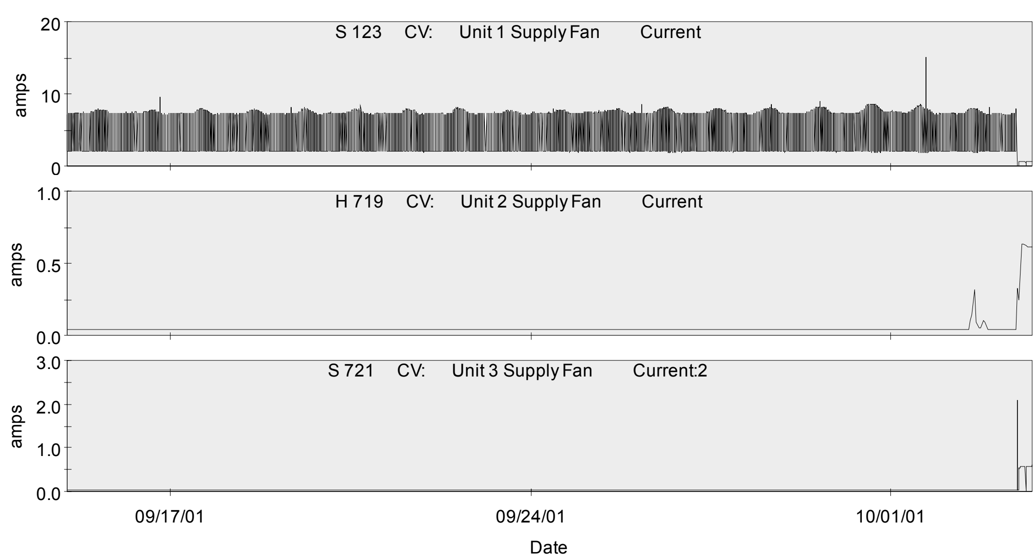
Monitoring Configuration

Short term diagnostic monitoring was performed on three of the units at this site. The units are classified by the following model numbers: 582AEW048090AAAG, 582AEW036060AAAF and 582APW030060AAAD. The on site name for these units are Unit 1, Unit 2 and Unit 3 respectively.

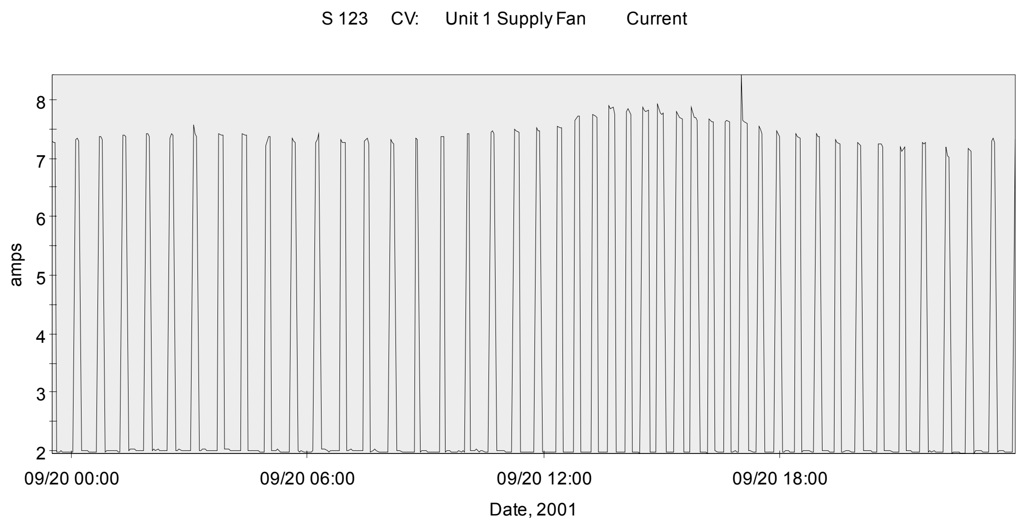
Fan Schedules

The operation of the three units monitored does not follow the occupancy schedule of the building. Unit 582AEW048090AAAG cycled from off to cooling at an average rate of two times per hour at all hours of the day. The other two units remained off during the entire monitoring period.

This figure displays the current for each of the units over time. Each series of data, from top to bottom represents a different unit. The amperage is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.



Unit 582AEW048090AAAG 24 hours of cycling



Fan Operation

None of the units operated in fan only mode during the monitoring period. The supply fan in all of the units should run continuously while the building is occupied in order to provide adequate ventilation.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Other Issues

During the monitoring period two of the units, 582AEW036060AAAF and 582APW030060AAAD, did not run. It appears that the other unit, 582AEW048090AAAG, is compensating for the failed units by providing additional cooling. The strain of meeting additional cooling loads can shorten the life and decrease the efficiency of the unit providing the additional cooling.

Site 11 - IDS - Disney Offices

The IDS - Disney Office at 2250 South Sequoia is a single story 610,000 square foot building. The majority of the space is used for unconditioned storage; a small portion is conditioned office space.

Heating and cooling for the building is provided by three- and four-ton Carrier packaged air conditioners. None of the units are equipped with economizers, which modulate outside air proportions and provide free cooling when conditions permit. Carrier thermostats control the HVAC system.

Monitoring Configuration

Short-term diagnostic monitoring was performed on three of the units at this site. The units are classified by the following serial numbers: 0600G20154, 0600G20170, and 1200G20169. The on-site names for these units are AC-2, AC-3 and AC-6 respectively.

Economizer Operations

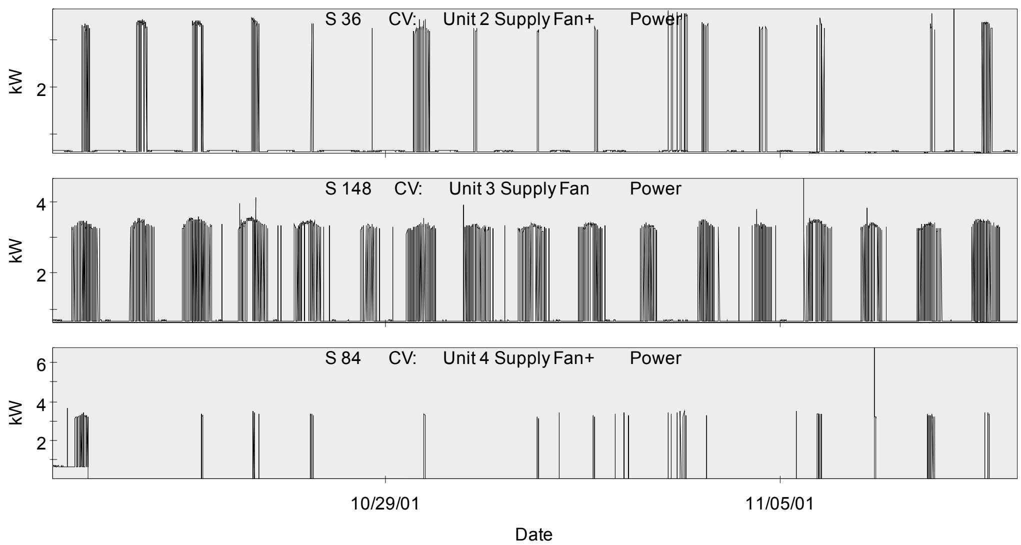
None of the units monitored had economizers.

Fan Schedules

The supply fan in unit 0600G20170 ran continuously during the monitoring period. The supply fan in units 1200G20074 and 1200G20169 cycled with compressor operation.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Fan Power vs. Time



Fan Power

ARI ratings are based on a supply fan power of 365W/1000 cfm. On-site testing showed an average of 376W/1000 cfm for the three units monitored.

Simultaneous Heating and Cooling

During the monitoring period each of the units had the opportunity to run in both heating and cooling mode. No simultaneous heating and cooling occurred.

Maintenance Condition

All of the units appeared to be in good condition. At the time of the monitoring period the filters in the units were clean and it appeared that the units were regularly serviced and well cared for.

Site 15 - Lucky Savon Supermarket La Mesa

The Lucky Savon Supermarket at 8920 Fletcher Parkway in La Mesa is a 55,000 square foot building. The space is divided between conditioned sales and unconditioned storage.

Heating and cooling for the building is provided by Trane packaged air conditioners. The units are equipped with either single point enthalpy or single point temperature economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The unit serial numbers are: N48102900D, N48102869D, N48102901D, and N48102869D. The on-site numbers for these units are RTU-1, RTU-2, RTU-3, and RTU-4 respectively.

Economizer Operations

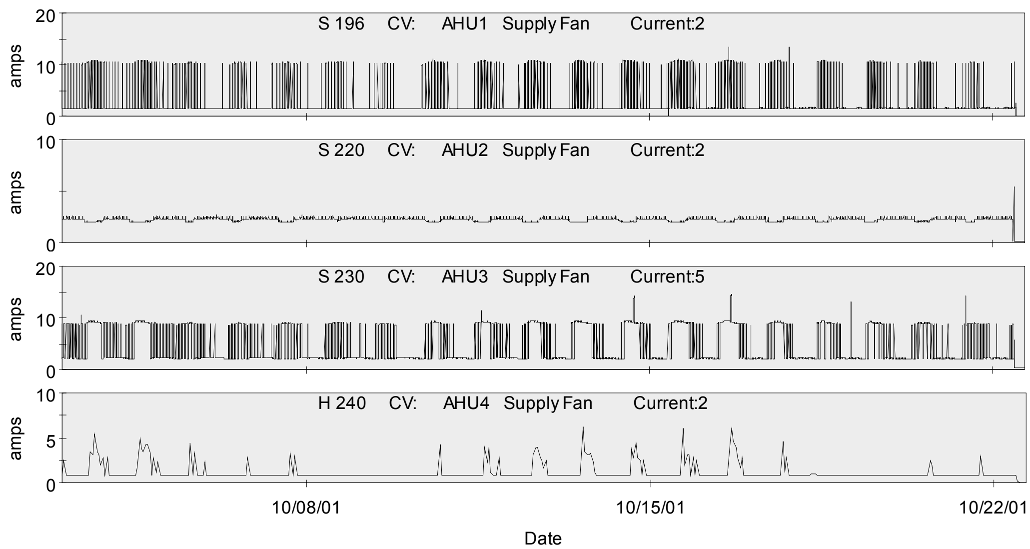
The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period.

Fan Operation

In all of the units the supply fan ran continuously during the monitoring period.

This figure displays the current for each of the units over time. Each series of data (from top to bottom) represents a different unit. The current is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Supply Fan Power vs. Time



Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during milder months.

Maintenance Condition

At the time of the site visit it appeared that the units were in need of scheduled maintenance and cleaning.

Other Issues

During the monitoring period, unit N48102869D never ran in cooling mode. The other three units cycled in and out of cooling mode in a regular pattern.

Sam's Club

The Sam's Club at 12540 Beach Blvd in Stanton is a 90,000 square foot building. The majority of the space is conditioned and used for retail sales. Heating and cooling for the building is provided by ten- and fifteen-ton Lennox packaged air conditioners. None of the units are equipped with economizers to modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 5696E02444, 5696G02087, 5696G02085, and 569B00116. The on-site numbers for these units are RTU-1, RTU-5, RTU-8, and RTU-10 respectively.

Economizer Operation

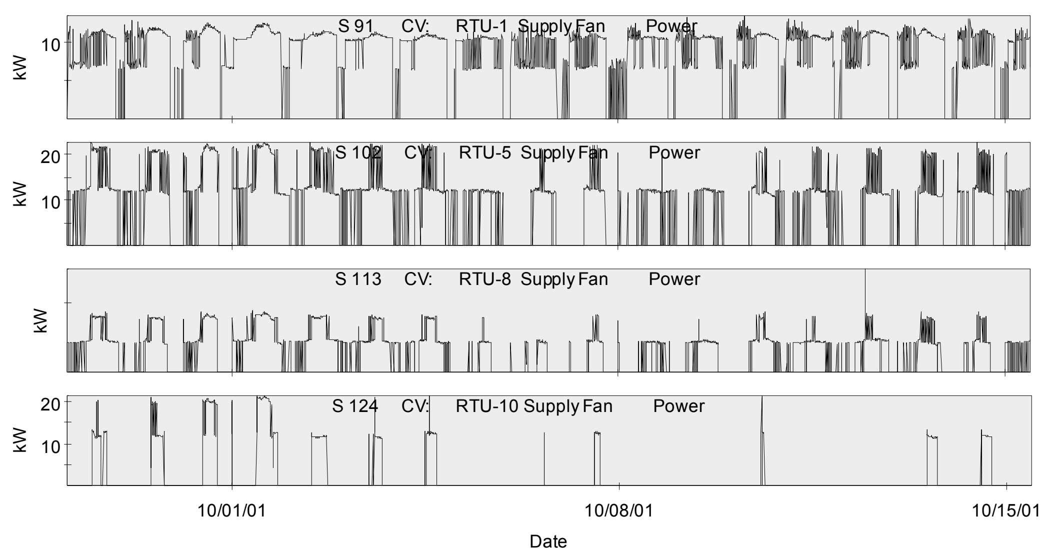
None of the units had economizers.

Fan Schedules

The operation of the units did not appear to follow any schedule. The units all ran at all times of the day.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit Power vs. Time



Fan Operation

In each unit the supply fan cycled with calls for cooling instead of providing continuous outside air.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during milder months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units appeared dirty. At the time of the site visit it appeared that the units were in need of maintenance and cleaning.

Site 17 - Barstow Auto Zone

Barstow Auto Zone at 1050 East Main Street in Barstow is a single story 5551 square foot building. The space is used for retail sales. Heating and cooling for the building is provided by five-ton Carrier packaged air conditioners. None of the units are equipped with economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on all three of the units at this site. The units are classified by the following serial numbers: 0698692449, 089620406 and 3698629494.

Economizer Operation

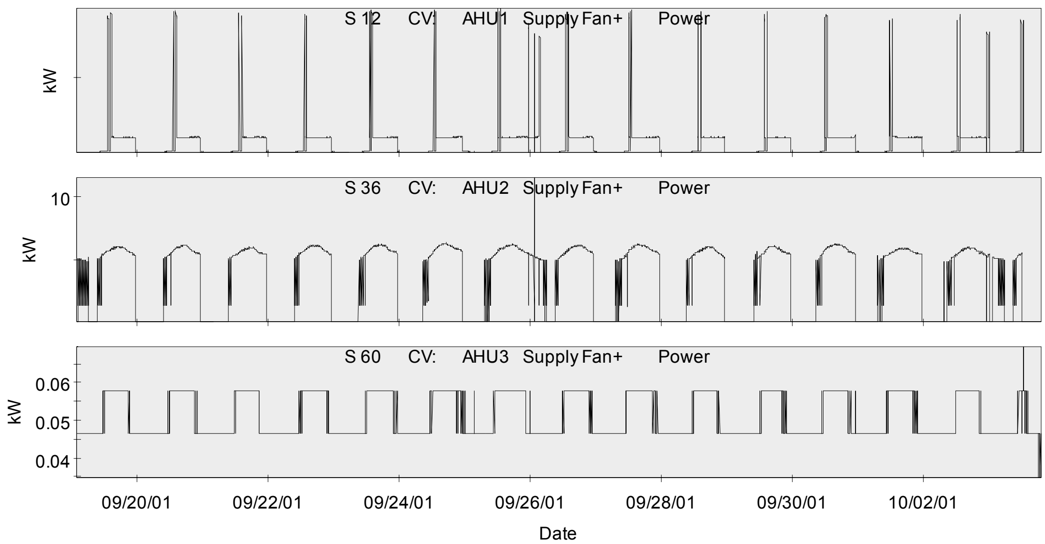
None of the units at this site had economizers.

Fan Schedules

During the monitoring period the supply fans schedule followed the occupancy schedule of the building.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

The supply fan in unit 0698692449 cycled independently of the compressor. The supply fan in unit 089620406 cycled with calls for cooling. Unit 3698629494 did not run during the monitoring period.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Other Issues

The three units supply heating and cooling directly to the same space. The thermostats for all three units are located together on one wall. Short term diagnostic monitoring shows that unit 089620406 provided nearly all of the cooling for the building, and units 0698692449 and 3698629494 provided little or no cooling to the space. The thermostats need to be calibrated to ensure that the units all come on when there is a call for cooling.

By relying on a single unit to supply the majority of cooling for the building you shorten the life span and decrease the efficiency of the unit.

Unit 3698629494 did not run at all during the monitoring period. It is possible that this is the result of a malfunction in the unit.

Site 24 Cantoni Furniture

Cantoni Furniture, at 8650 Research Drive in Irvine is a two story 41,684 square foot building. Cooling for approximately 5783 is provided by small packaged HVAC equipment. The majority of the space is conditioned and used for retail sales, while the remainder is used for unconditioned storage. Heating and cooling for the building is provided by Carrier packaged air conditioners. All of the units over 7 tons in size are equipped with differential enthalpy economizers which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 4199G30492, 4199G30616, 3998G42916 and 0799G20227. The on-site numbers for these units are HP-5, HP-6, HP-7 and HP-9 respectively.

Economizer Operations

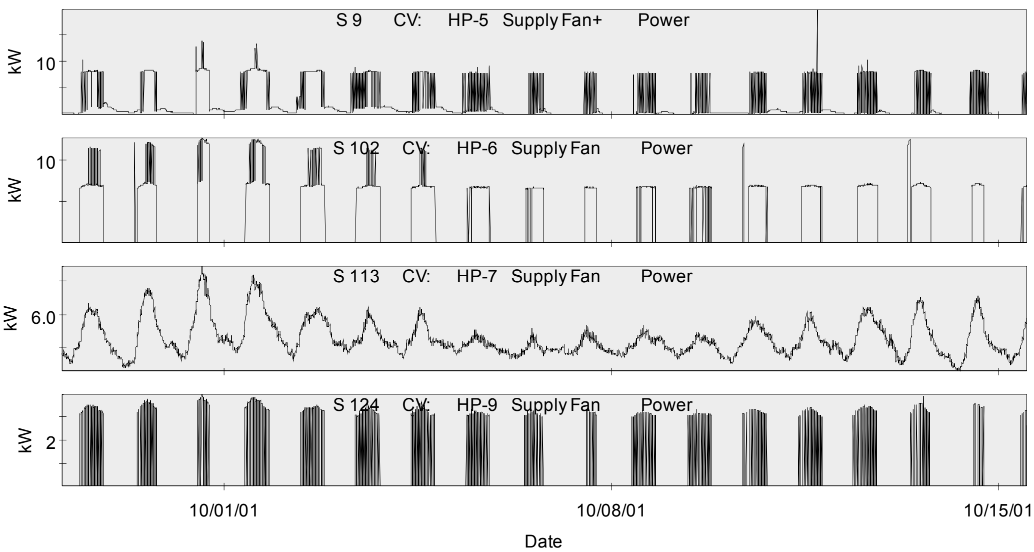
The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period.

Fan Schedules

The supply air fans respond appropriately to the schedule of the building. The supply air fans circulate fresh air during the occupied period and remain off when the building is unoccupied.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each of the units monitored the supply fans cycled with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period only one of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 29 - Otay Offices

The Otay Offices building at 8490 Avenida de la Fuente is a 7,947 square foot building. Heating and cooling for 5,542 square feet of the building is provided by Rheem packaged air conditioners. All of the units are equipped with either single-point temperature or single-point enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on three of the units at this site. The units are classified by the following serial numbers: 1R6021ADAAF110028771, 1R5813ADAAF439905942, and 2B6329ADAAF110030922. The on-site numbers for these units are RTU-5, RTU-1, and RTU-2 respectively.

Economizer Operations

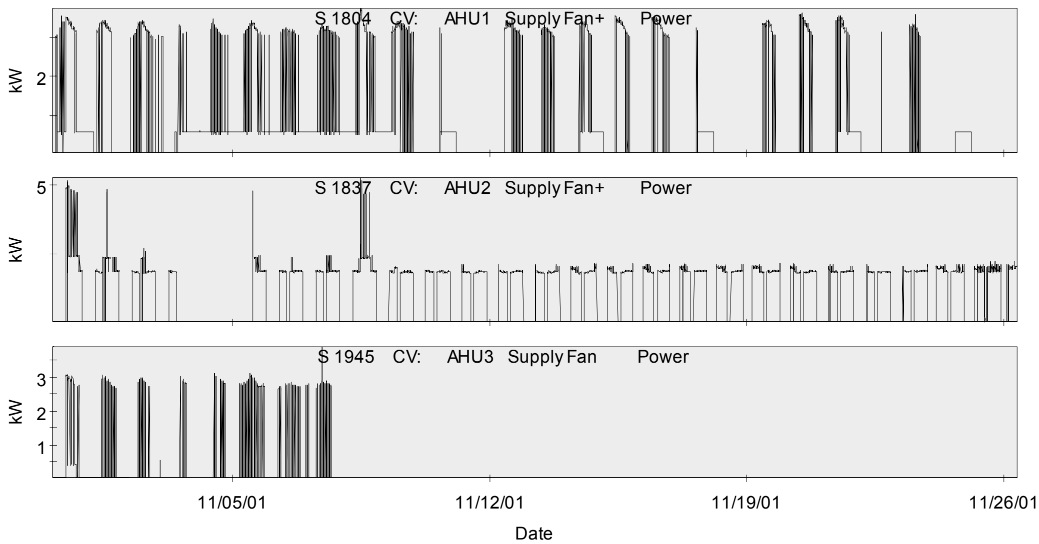
The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period. The current percentage of outside air for all of the units varies from plan specifications.

Fan Schedules

Monitoring shows that none of the units follow an operation schedule. The units should be scheduled off when the building is unoccupied.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan cycled with the unit compressor. The supply fans should remain on when the units are occupied in order to allow fresh air to circulate through the building.

Simultaneous Heating and Cooling

During the monitoring period it appears that some simultaneous heating and cooling did occur. Unit 1R6021ADAAF110028771 ran in cooling mode while unit 1R5813ADAAF439905942 was heating.

Maintenance Condition

At the time of the site visit all of the units monitored appeared to be in need of maintenance and cleaning. One of the compressors in RTU-2 is not operating, and the evaporator coil in RTU-1 is covered with ice.

Other Issues

The thermostat location within the building appears to be inappropriate. During the site visit only thermostat was found. The thermostat is located in an area that has a lower cooling load than the rest of the space. As a results the other areas are under cooled.

Site 37 - Radiological Associates

The Radiological Associates building at 1500 Expo Parkway in Sacramento is a 34,500 square foot building. Heating and cooling for the building is provided by Carrier packaged air conditioners. All of the units are equipped with differential temperature economizers, which modulate outside air proportions and provide free cooling when conditions permit

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: P121033OD, P11104392D, P02103151D and P091014850. The on-site numbers for these units are AC-11, AC-12, AC-13, and AC-10 respectively.

Economizer Operations

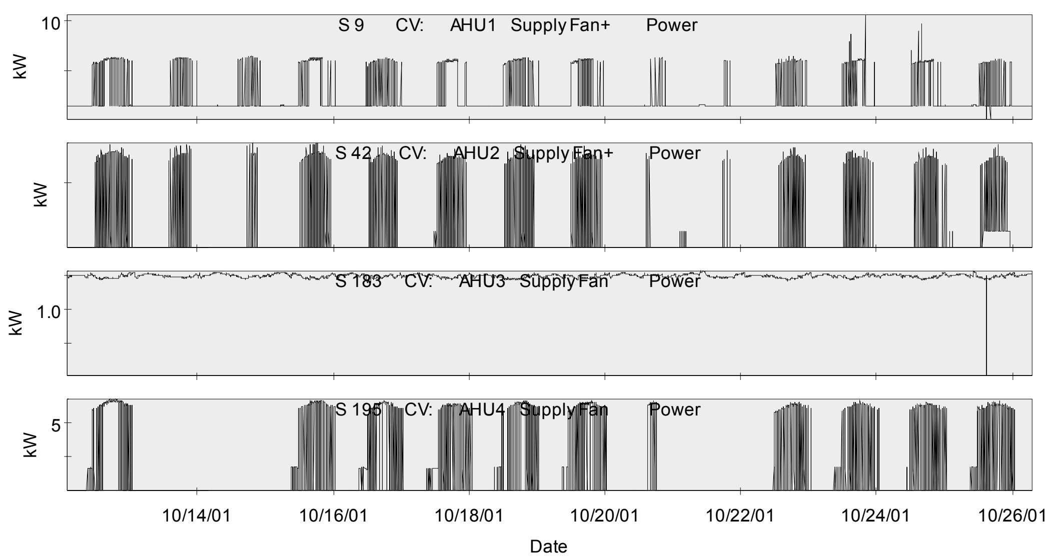
The results of diagnostic monitoring show that the economizer dampers in units P121033OD and P11104392D failed to modulate during the monitoring period. The economizers in the other units operated properly.

Fan Schedules

The supply fans in units P121033OD and P02103151D remained on during the entire monitoring period. The supply fans do not follow any building setback schedule.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

The supply fans in units P11104392D and P091014850 cycled with the compressors. The fans should run continuously while the building is occupied to provide continuous outside air to the space.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Other Issues

During the monitoring period the compressor in one of the units, P02103151D, did not run. It appears that the other units are compensating for the failed unit by providing additional cooling. The strain of meeting additional cooling loads can shorten the life and decrease the efficiency of the units providing the additional cooling.

Site 39 - Sagebrush Medical Plaza

The Sagebrush Mental Health Clinics Elderlife Addition at 1111 Columbus Ave in Bakersfield is a single story 2,400 square foot building. Heating and cooling for the building is provided by numerous Trane and Day & Night packaged air conditioners. The Trane units are equipped with differential temperature economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on three of the units at this site. The units are classified by the following serial numbers: P31103851D, P30100846D, and 2995620888. The on-site numbers for these units are AHU-23, AHU-24, and AHU-30 respectively.

Economizer Operations

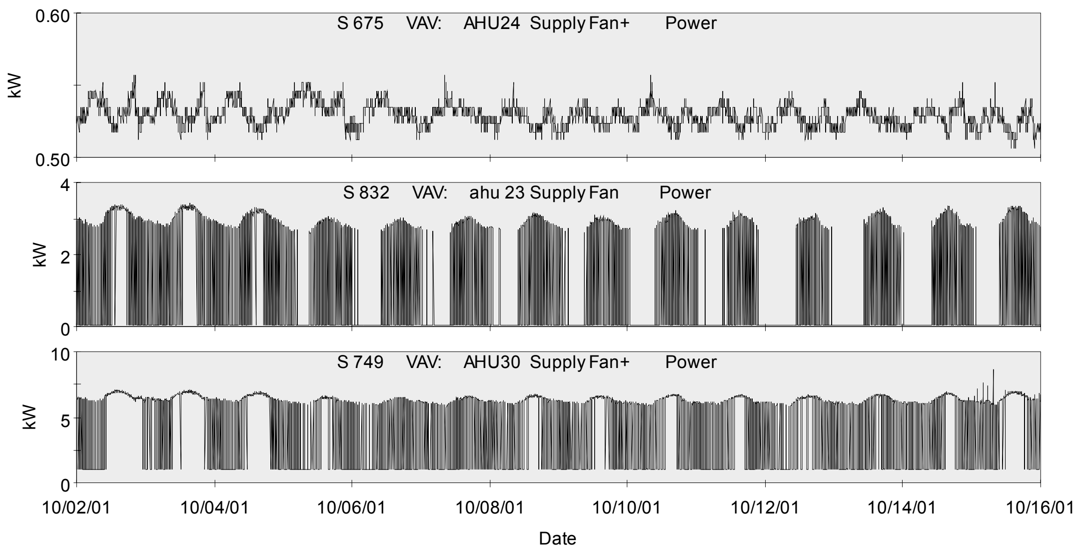
The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period.

Operation Schedules

The units do not follow an operation schedule. All of the units monitored ran at all hours of the day every day of the week. Unit 2995620888 did not turn off during the monitoring period.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each of the units the supply fan cycled with the compressor. The supply fans should run independently of the compressors to allow outside air to circulate continuously throughout the building.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 49 - Apple Valley Science and Technology Lewis Center

The Apple Valley Science and Technology Lewis Center is an 11,125 square foot building. The space is conditioned and used for various educational purposes. Heating and cooling for the building is provided by Trane packaged air conditioners. The larger units are equipped with differential temperature economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following numbers: AC-6, AC-5, AC-3, and AC-4. AC-6 and AC-5 are six and one-half ton units, AC-3 is two tons, and AC-4 is two and one-half tons. The units all serve the NASA research portion of the building.

Economizer Operations

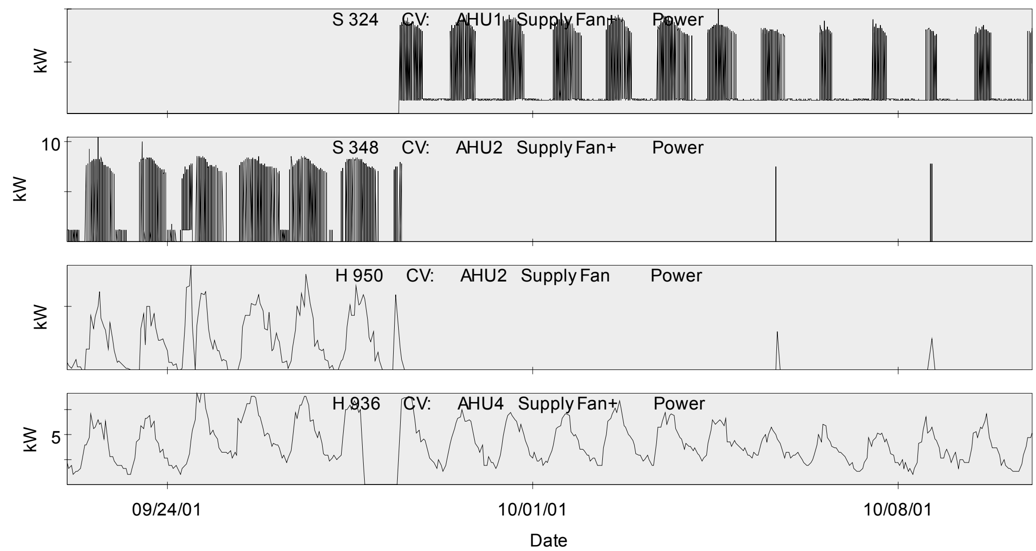
The economizers failed to respond to spot checking in both of the units with economizers. The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period.

Fan Schedules

The supply fans in all of the units ran continuously during the monitoring period. This may be necessary due to the high equipment density in the space.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 51 - Victory Outreach Church

The Victory Outreach Church at 990 West Mill Street in San Bernardino is a single story 38,000 square foot building. This report pertains to the 11,450 square foot area that houses the sanctuary. Heating and cooling for the building is provided numerous York packaged air conditioners. All of the units are equipped with single-point temperature economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on three of the units at this site. The units are classified by the following serial numbers: NGGM090322, NGGM092689, and NGM089500. The on-site numbers for these units are AC-3, AC-4, and AC-8 respectively.

Economizer Operations

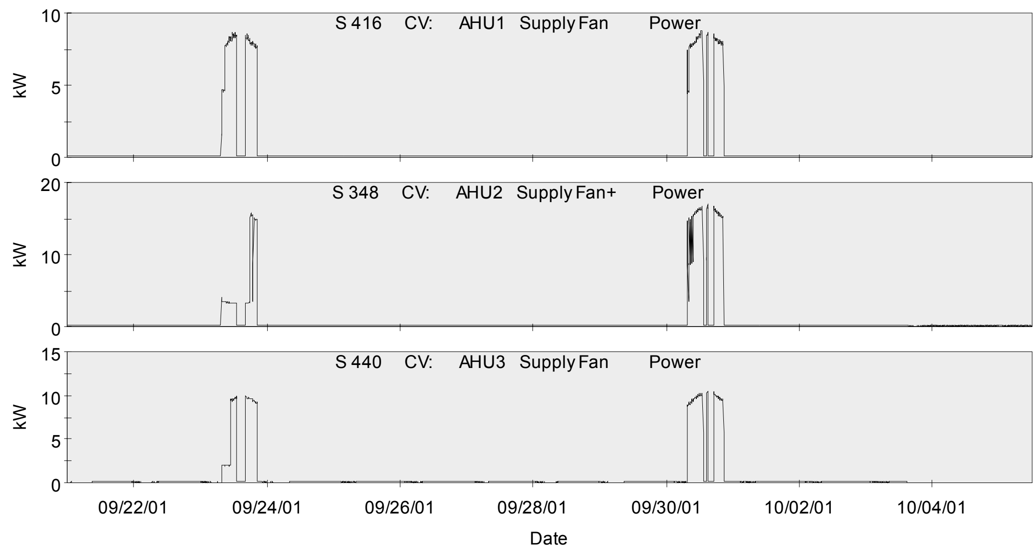
The economizers failed to respond to spot checking two of the three units tested. The results of diagnostic monitoring show that the economizer dampers did modulate in the third unit during the monitoring period.

Fan Schedules

Heating and cooling for the building is manually scheduled by building occupants. The units are turned on at the breaker during high occupancy periods and remain off the rest of the time.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

The units did not appear to be well maintained. The filters were very dirty and needed to be replaced. The exterior panels on some of the units were not properly attached.

Site 53 - St. Michael's Episcopal Church School

St. Michael's Episcopal Church School at 2140 Mission Ave, in Carmichael is a 34,000 square foot building. The majority of the space is conditioned and used for educational purposes, while the remainder is used for unconditioned storage.

Heating and cooling for the building area studied is provided by Carrier packaged air conditioners. All of the units are equipped with differential enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 3499G20334, 2599G20294, 2199G20521 and 4498G20853. The on site numbers for these units are RTU-2, RTU-3, RTU-4 and RTU-5 respectively.

Economizer Operations

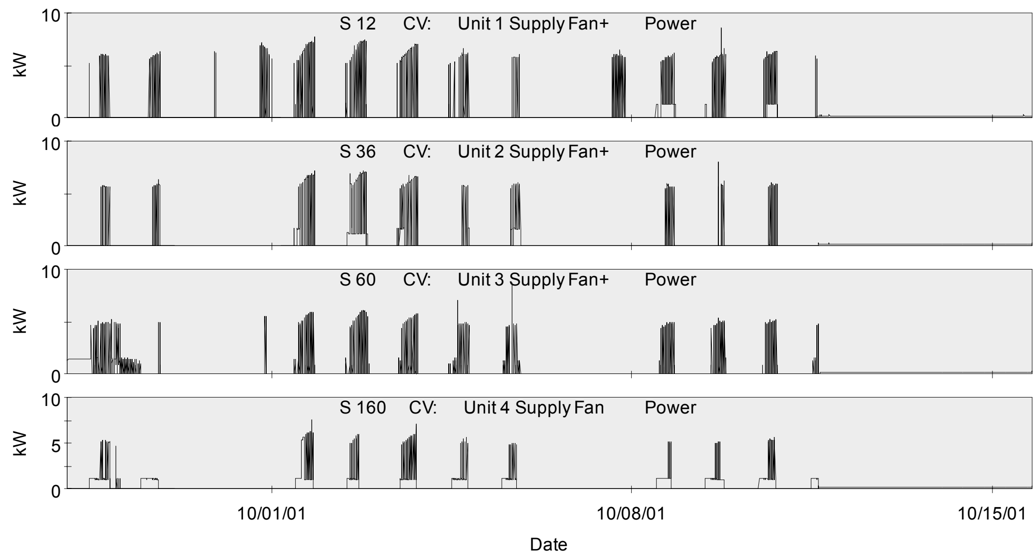
The results of diagnostic monitoring show that the economizer damper in unit 4498G20853 did not modulate during the monitoring period.

Fan Schedules

The supply fans in all of the units follow the building use schedule.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In units 2599G20294 and 4498G20853 the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling. The supply fans in units 3499G20334 and 2199G20521, however, cycled with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 55 - Jardiniere

The Jardiniere Restaurant is at 300 Grove St in San Francisco is housed in an historic building on the corner of Grove and Franklin streets.. The majority of the space is conditioned and used for restaurant seating, while the remainder is used for unconditioned storage.

Heating and cooling for 6,000 square feet of the restaurant is provided by four York packaged air conditioners. All of the units are equipped with differential enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: NDTM037847, NDFM043983, NBFM020636 and NBFM020639.

Economizer Operations

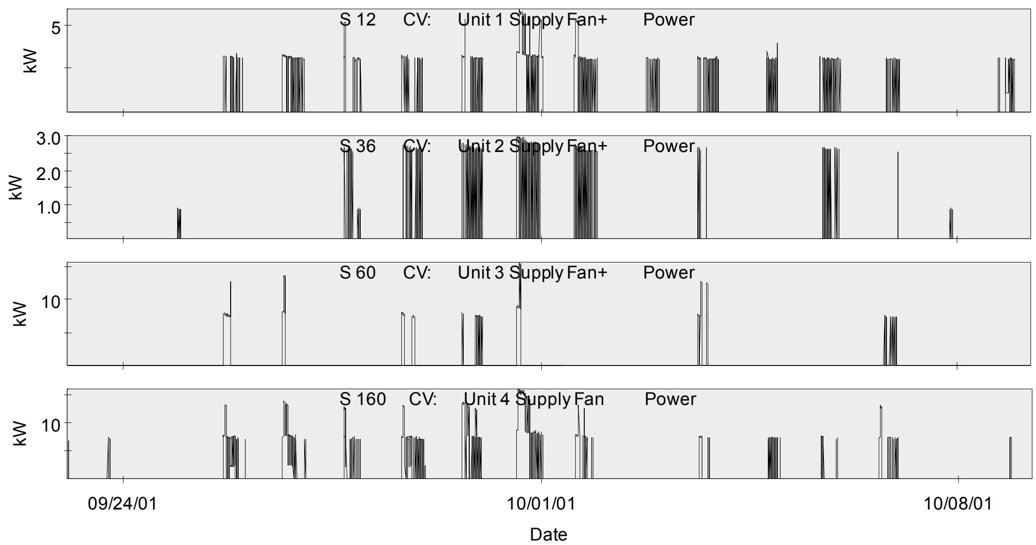
The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period.

Fan Schedules

The supply fans in all of the units follow the operation schedule of the restaurant.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In all of the units monitored the supply fans cycled with the compressor. The supply fans should run continuously while the building is occupied in order to provide adequate ventilation.

Simultaneous Heating and Cooling

During the monitoring period unit NDFM043983 ran in heating mode while the other three units were cooling.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 59 - Burger King Roseville

The Burger King at 111 South Harding Drive in Roseville is a single story 3,240 square foot building. The entire space is conditioned and used as a quick service restaurant.

Heating and cooling for the building is provided by Carrier packaged air conditioners. None of the units are equipped with economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

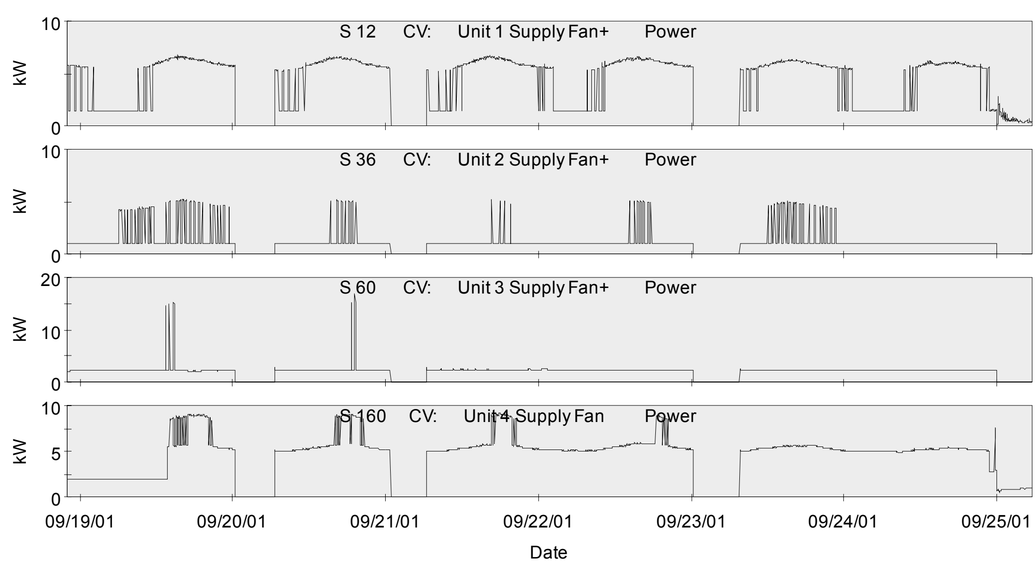
Short term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 0900G20223, 2599G20410, 1799G20479 and 4699G30267. The on site numbers for these units are AC-2, AC-3, AC-4 and AC-5 respectively.

Fan Schedules

The supply fans in all of the units respond appropriately to the building schedule.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Other Issues

The supply air temperature is unit 1799G20479 is above 60 degrees. There may be a number of reasons for the high supply air temperature such as high volumes of air movement or low refrigerant charge.

Site 60 - Jack In the Box Watsonville

The Jack In the Box at 1085 S. Green Valley Road in Watsonville is a single story 2,385 square foot building. The space is used as a quick service restaurant.

Heating and cooling for the building is provided by two York packaged air conditioners. Both of the units are equipped with single point enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short term diagnostic monitoring was performed on both of the units at this site. The units are identified by the following serial numbers: NKGM126007 and NANM001384. Unit NKGM126007 serves the kitchen. Unit NANM001384 serves the dining area.

Economizer Operations

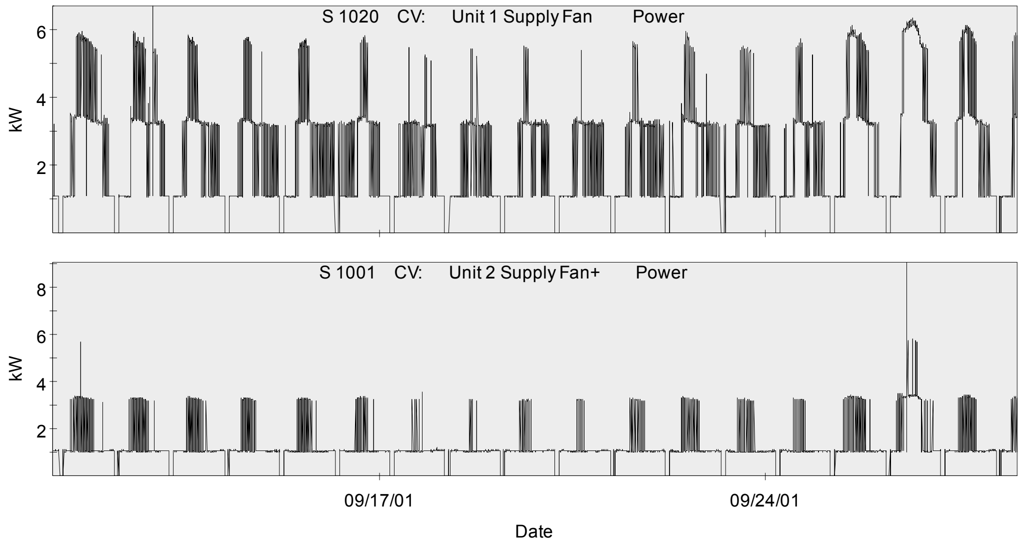
The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period. There were times during the monitoring period that cooling for the building could have been provided by economizer control of outside air, but was instead met by mechanical cooling.

Fan Schedules

The supply fans in both of the units followed the occupancy schedule of the building.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

No simultaneous heating and cooling occurred during the monitoring period. Unit NKGM126007 operated primarily in cooling mode. Unit NANM001384 operated primarily in heating mode.

Maintenance Condition

All of the units appeared to be in good condition. Although it appears that the units are regularly serviced and maintained, the filters were in need of replacement at the time of our visit.

Site 62 - Camino Real Marketplace

Camino Real Marketplace at 7004 Market Place Drive is a 7,598 square foot building. The majority of the space is conditioned and used for retail sales.

Heating and cooling for the building is provided by Carrier packaged air conditioners. The larger units are equipped with differential enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 3699G2041, 3599G20755, 3999G30302 and 3999G30302. The on site numbers for these units are RTU-13, RTU-14, RTU-15 and RTU-17 respectively.

Economizer Operation

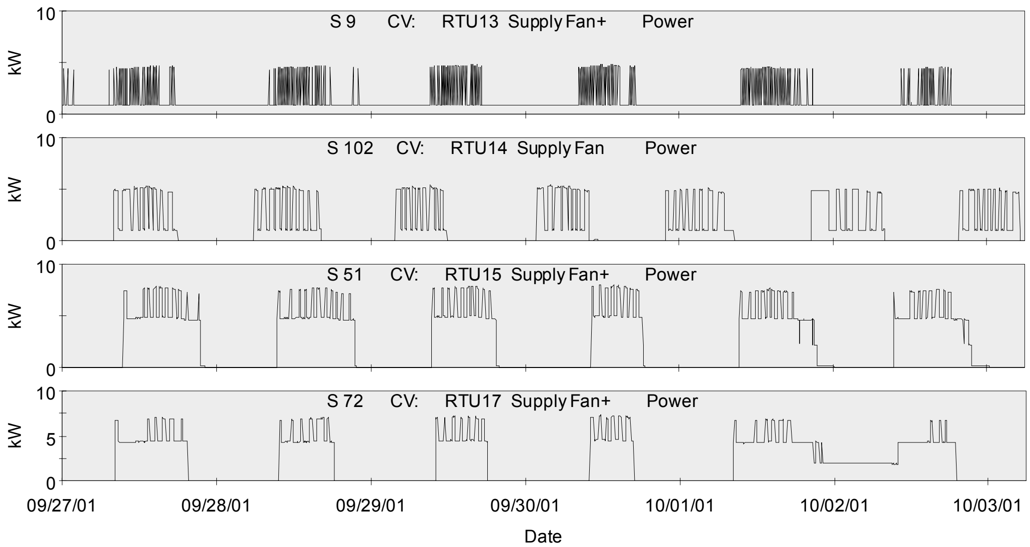
The results of diagnostic monitoring show that the economizer dampers did modulate during the monitoring period. There were times, however, that cooling for the building was provided by mechanical cooling when the cooling load could have been met by the economizer. The outside air fraction on both of the units with economizers is set to 45 percent. This may be higher than necessary.

Fan Schedules

The supply fan in unit 3699G2041 remained on constantly during the monitoring period. The supply fans in the other three units followed the building operation schedule.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

The units appear to need regular maintenance. The filters in the units are dirty and need to be changed.


RTU-17
Carrier
Weathermaster
SERIES

Site 63 - Babies “R” Us La Mesa

The Babies “R” Us at 8165 Fletcher Parkway in La Mesa is a single-story, 38,948 square foot building. The majority of the space is conditioned and used for retail sales, while the remainder is used for unconditioned storage.

Heating and cooling for the building is provided by numerous 15-ton Lennox packaged air conditioners. All of the units are equipped with differential enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit. The HVAC system is controlled by a NOVAR energy management and control system.

Short-term diagnostic monitoring was performed on three of the rooftop units at this site. The units are classified by the following serial numbers: 5692F03359, 5697F03360, and 5697F03357.

Fan Schedules

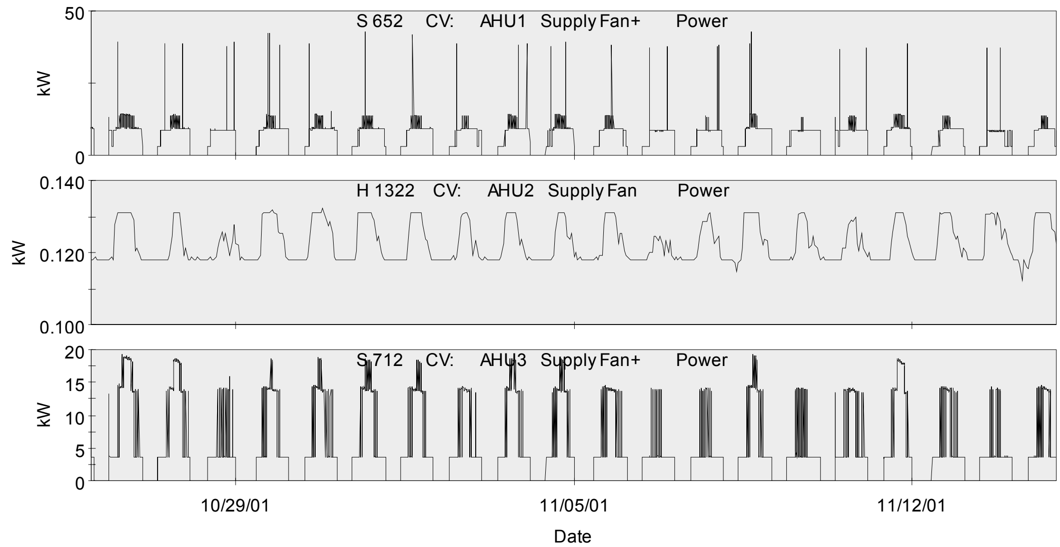
The NOVAR energy management system installed in the building is responding appropriately to the schedule of the building. The supply air fans allow fresh air to circulate during the occupied period and remain off when the building is unoccupied.

Fan Operation

In each unit, the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

The following graph demonstrates the fan power over time for all three units. Each of the measurements is for total unit power. The data shows the operation of the units over the two-week monitoring period. Fan only operation uses about four kW of power in each of the units, first stage cooling uses 12 kW and demand spikes above 12 kW represent second stage cooling. The .120 to .130 kW load of unit 2 is standby power use only.

Unit power vs. time



Simultaneous Heating and Cooling

During the monitoring period, none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good operating condition. The filters in the units were clean, and the exterior of each unit is well protected from environmental damage. It appears that the units are regularly serviced and well maintained.

Economizer Operations

The economizers failed to respond to spot checking in all three of the units. The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period.

Other Issues

During the monitoring period one of the units, #5697F03360, did not run. It appears that the other units are compensating for the non-operating unit by providing additional cooling. The strain of the additional cooling loads may shorten the life and decrease the efficiency of the units.

Site 65 - Michael's

Michael's at 25686 The Old Road N in Santa Clarita is a 20,381 square foot building. The majority of the space is conditioned and used for retail sales, while the remainder is used for unconditioned storage. Heating and cooling for the building is provided by numerous Lennox packaged air conditioners. All of the units are equipped with differential enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 5697604517, 5697C04435, 5697604436 and 5697C04435.

Economizer Operations

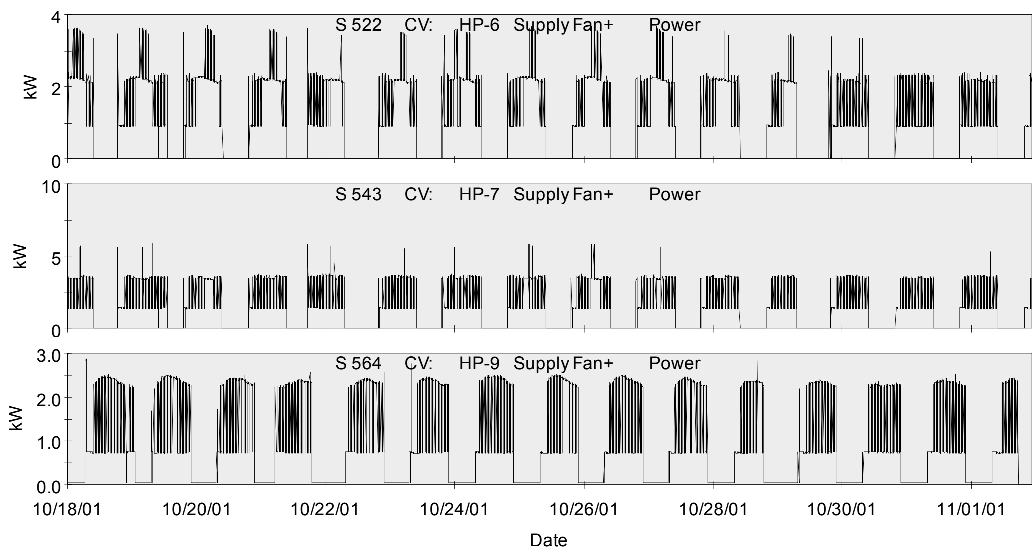
The economizers failed to respond to spot checking in all three of the units. The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period.

Fan Schedules

The operation of the supply fans in all of the units appears to follow the building use schedule.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Other Issues

During the monitoring period one of the units, 5697F03360 did not run. It appears that the other units are compensating for the failed unit by providing additional cooling. The strain of meeting additional cooling loads can shorten the life and decrease the efficiency of the units providing the additional cooling.

Site 67 - Carl's Jr. Restaurant Westminster

The Carl's Jr. at 13425 Beach Blvd. In Westminster is a single story 3,100 square foot building. The entire space is conditioned and used as a quick service restaurant. Heating and cooling for the building is provided by two York packaged air conditioners. Both of the units are equipped with single-point enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short term diagnostic monitoring was performed on both of the units at this site. The units are classified by the following serial numbers: NMFM137827 and NMFM139352. Unit NMFM137827 serves the kitchen. Unit NMFM139352 serves the dining area.

Economizer Operation

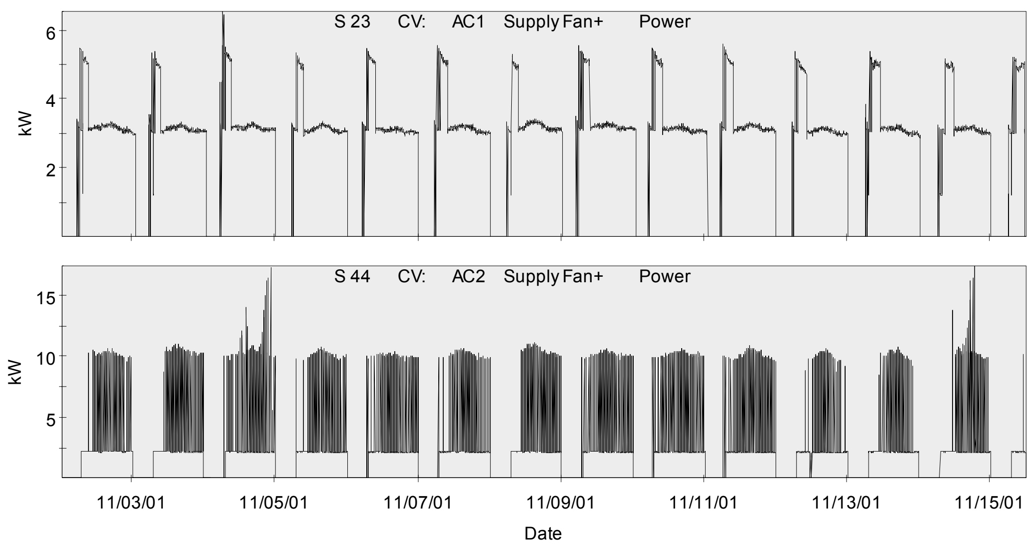
The economizer dampers in both of the units moved in response to changes in climatic conditions.

Fan Schedules

The units are scheduled to respond appropriately to the building use schedule.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

Both of the units appear to need cleaning and maintenance. The filters are clogged with dirt from the kitchen exhaust. Small amounts of rust have built up on one of the economizer dampers. At the time of the site visit there was a significant amount of ice buildup on the evaporator of one of the units

Site 77 - School of Cosmetology and Adult Handicapped Ed

The School of Cosmetology and Adult Handicapped Ed at 3340 East Los Angeles St. in Simi Valley is a 15,195 square foot building. Small packaged HVAC equipment is used to condition 3,163 square feet of the facility, the information in this report refers to this portion of the building.

Heating and cooling for the building is provided by Carrier packaged air conditioners. The units are equipped with single-point enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short term diagnostic monitoring was performed on two of the units at this site. The units are classified by the following serial numbers: 1497G20367 and 1497G20449. The on site names for the units are AC-2 and AC-6 respectively.

Economizer Operations

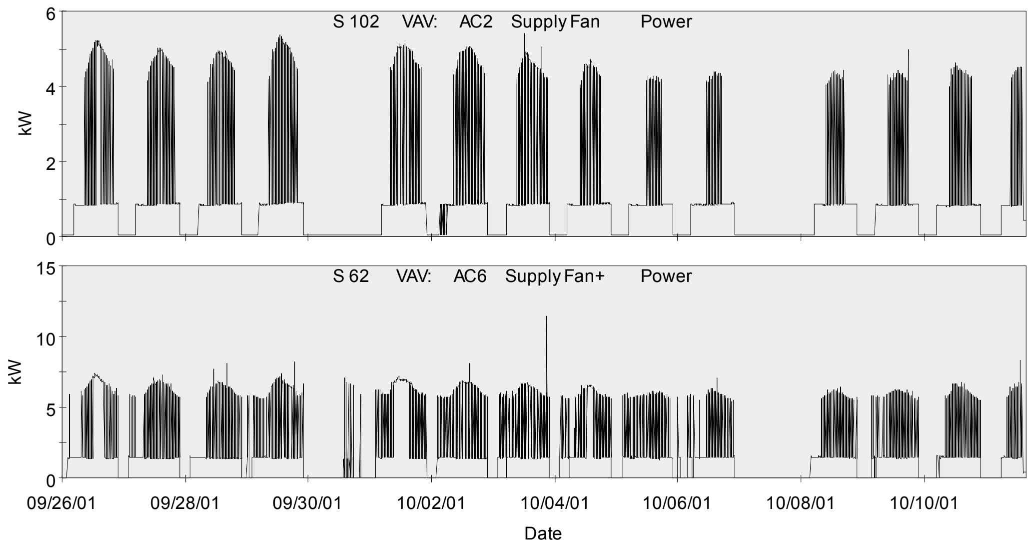
The economizers failed to respond to spot-checking. The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period.

Fan Schedules

The operation of the units follows the building use schedule.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period no simultaneous heating and cooling occurred. Unit 1497G20449, however, did operate in heating mode within five minutes of unit 1497G20367 cooling.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 80 - Henry J Kaiser High School

Henry J Kaiser High School, at 11155 Almond Ave in Fontana is a multi building campus. The building monitored houses the library and administration areas as well as classrooms. The space is conditioned and used for educational purposes. Heating and cooling for the building is provided by Carrier packaged air conditioners. All of the units are equipped with single-point temperature economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 0798630320, 0798630321, 0898620310 and 0898620316. The on site names for the units are AC 11, AC 12, AC 8 and AC 9 respectively.

Economizer Operations

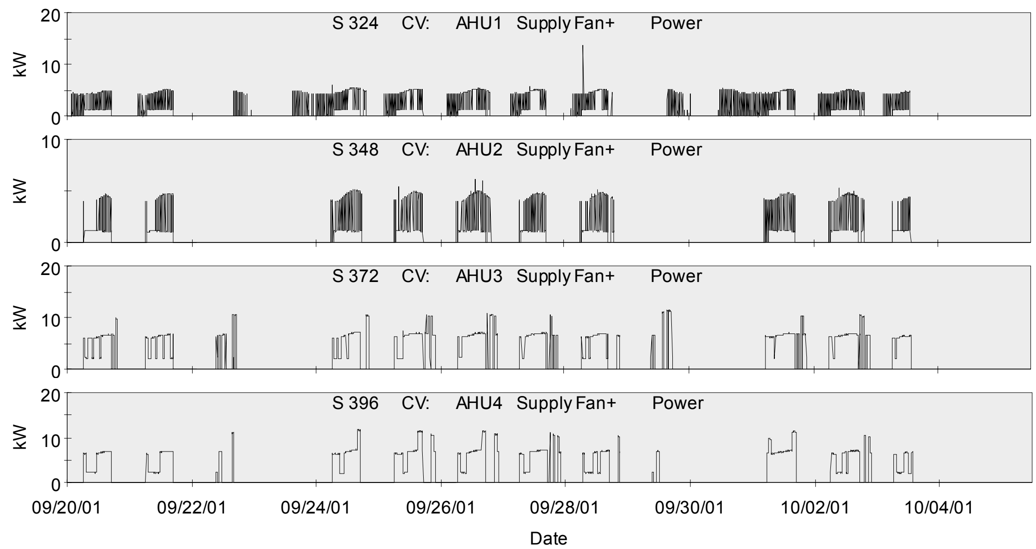
The economizers failed to respond to spot checking in all of the units. The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period.

Fan Schedules

The supply fans in all of the units respond appropriately to the building schedule.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 133 - Folsom High School Building

Folsom High School, at 1655 Iron Point Road in Folsom, is a 152,714 square foot conditioned high school. Heating and cooling for the building is provided by five-ton BDP packaged air conditioners. All units are equipped with differential enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 4397G20224, 4397G20226, 4397G20223, and 4397G20242. These units are labeled as AC-14L, AC-15L, AC16L, and AC-19L respectively.

Economizer Operations

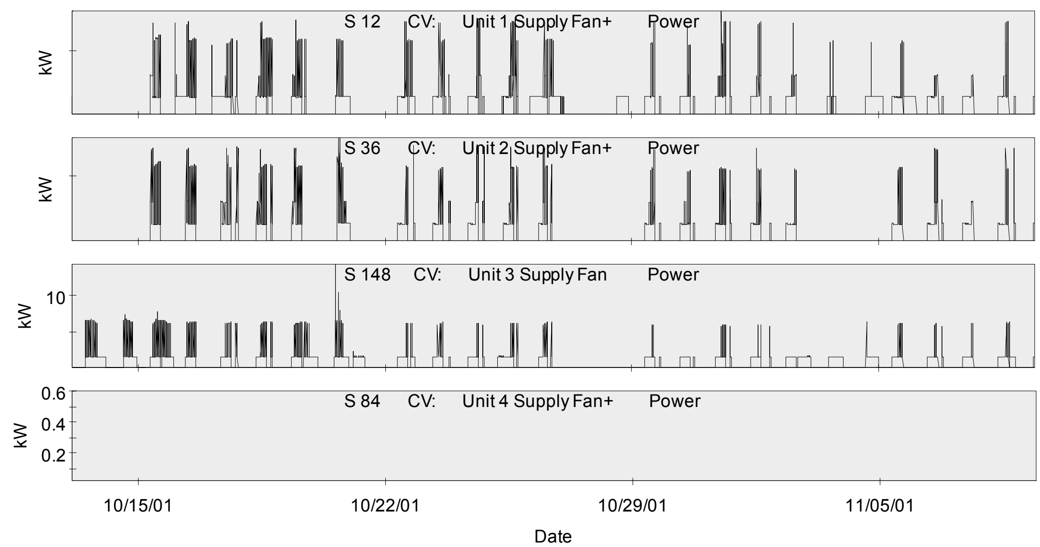
The results of diagnostic monitoring show that the economizer dampers did not modulate during the monitoring period. The outside air dampers appear to be locked at an outside air fraction of between 10 and 20 percent.

Fan Schedules

The energy management system installed in the building responds appropriately to the schedule of the building. The supply air fans allow fresh air to circulate during the occupied period and remain off when the building is unoccupied.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Fan Power vs. Time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Fan Power

ARI ratings are based on a supply fan power of 365W/1000 cfm. All of the units tested higher than the rated W/cfm. On-site testing showed an average of 428W/1000 cfm for the units monitored.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean and it appears that the units are regularly serviced and well maintained.

Other Issues

During the monitoring period one of the units, 4397G20242, did not run. It appears that the other units may be compensating for the failed unit by providing additional cooling. The strain of meeting additional cooling loads may shorten the life and decrease the efficiency of the units providing the additional cooling.

Site 146 - Safeway, Santa Rosa

The Safeway at Fourth Street and Farmers Lane in Santa Rosa is a single story 44,000 square foot building. The space is used for retail sales and unconditioned storage.

Heating and cooling for the building is provided by three- and five-ton Carrier packaged air conditioners. The units are equipped with differential enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on three of the units at this site. The units are classified by the following serial numbers: 2100G24486, 2400G20333, and 2400G20334. These on-site names for these units are AC-2, AC-3, and AC-4 respectively.

Economizer Operations

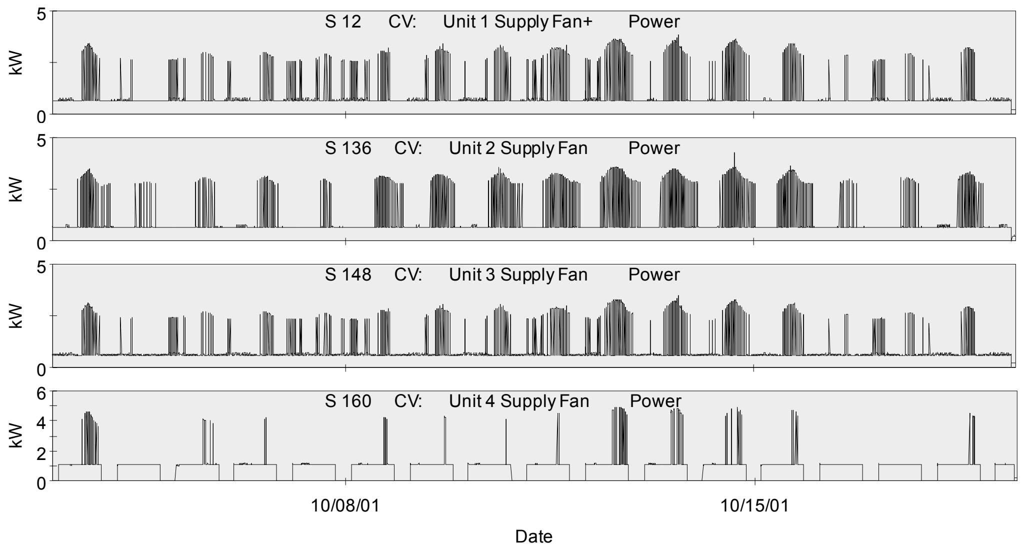
The results of diagnostic monitoring show that the economizer dampers on units 2100G24486 and 2400G20334 did not modulate during the monitoring period.

Fan Schedules

The supply fans in units 2100G24486 and 2400G20333 ran continuously during the monitoring period. The supply fan in unit 2400G20334 cycled daily with the building operation.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Fan Power vs. Time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period the units cycled frequently between heating and cooling. The units often ran in competing modes.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and well maintained.

Site 147 - Chevron, Oakland

The Chevron station/Food Mart at 5500 Telegraph in Oakland is a 7,525 square foot building. The space is conditioned and used for retail sales.

Heating and cooling for the building is provided by one seven-ton, and one half-ton, and one three-ton York packaged air conditioners. The units are equipped with single point enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short term diagnostic monitoring was performed on two of the units at this site. The units are classified by model numbers B3CH090-A25STB and B3CH036-A258D. The on-site numbers for these units are AC-2 and AC-1 respectively.

Economizer Operation

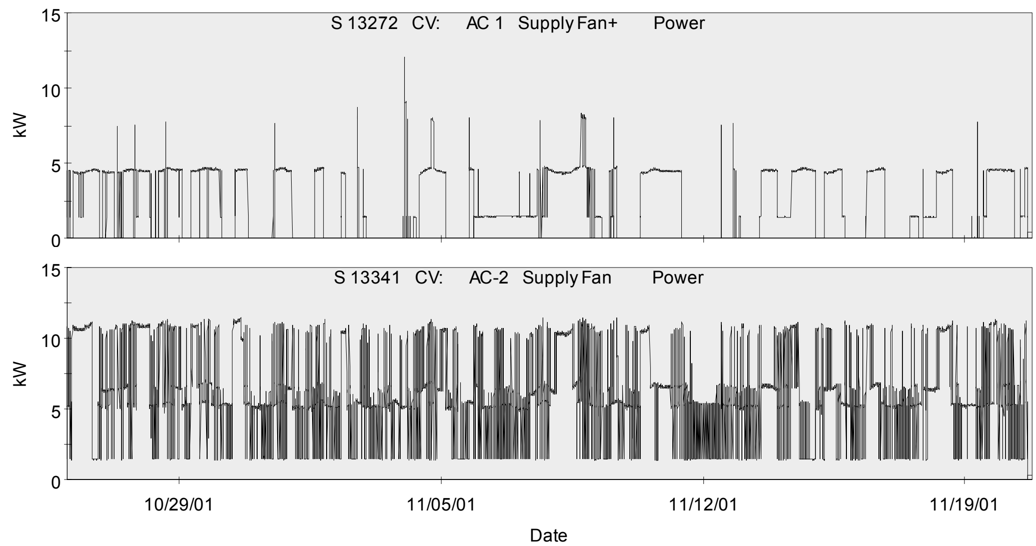
The economizers appear to be operating properly.

Fan Schedules

Neither unit appears to be responding to a supply fan schedule. The thermostats that are currently installed in the building are not capable of scheduling the fan operation independently of heating and cooling.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Fan Power vs. Time



Fan Operation

The supply fan in unit B3CH090-A25STB cycled with calls for heating and cooling. The supply fan in unit B3CH036-A258D remained on continuously during the monitoring period. The supply air fans should instead remain on while the building is occupied and turn off when it is unoccupied.

During the initial site visit it became clear that the building occupants did not understand the thermostats that they were operating. Whenever there was discomfort, the levers of the heating and cooling setpoint were moved up and down together. This accounts for much of the erratic behavior of the HVAC system. During the second visit, the proper operation of a heating/cooling thermostat was explained to the management at great length.

Fan Power

ARI ratings are based on a supply fan power of 365W/1000 cfm. Both of the units tested higher than the rated W/cfm. On-site testing showed an average of 453W/1000 cfm for the units monitored.

Simultaneous Heating and Cooling

During the monitoring period both units switched frequently between heating and cooling. Often when one unit operated in heating mode, the other was in cooling mode.

Maintenance Condition

All of the units appear to be in good condition. The filters in the units are clean and it appears that the units are regularly serviced and maintained.

Site 152 - Wetzel Moving and Storage

Wetzel Moving and Storage at 124398 Osborne Place in Pacoima is a 38,000 square foot building. The majority of the space is used for unconditioned storage and a small portion is conditioned office space. Heating and cooling for the building is provided by Rheem packaged air conditioners. The units do not have economizers to modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on two units at this site. The serial numbers for these units are 41639259800360 and 5528F309815975. The on-site numbers for these units are AC-2 and AC-1 respectively.

Economizer Operation

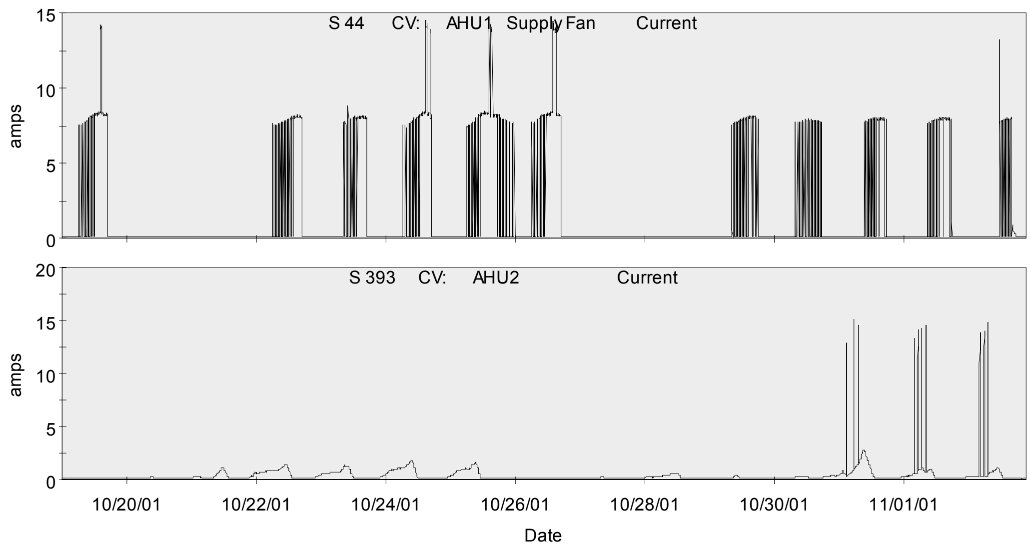
There were no economizers on the units at this site.

Fan Schedules

The supply fans for both units appear to follow the occupancy schedule of the building. They remain off at night and during the weekends.

This figure displays the current for each of the units over time. Each series of data (from top to bottom) represents a different unit. The amperage is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Fan Power vs. Time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

The units had the opportunity to operate in both heating and cooling mode during the monitoring period. No simultaneous heating and cooling occurred during this time.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 161 - Adventure Christian Church

Adventure Christian Church, at 6401 Stanford Ranch Rd., in Roseville is a 28,000 square foot building, 4,800 square feet of which was studied; and is conditioned by packaged air conditioners.

Heating and cooling for the building is provided by York packaged air conditioners. None of the units are equipped with economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: NGGM092878, NGGM092876, NHGM096500, and NHGM095852. The on-site numbers for these units are AC-4, RTU-15, RTU-1, and RTU-2 respectively.

Economizer Operation

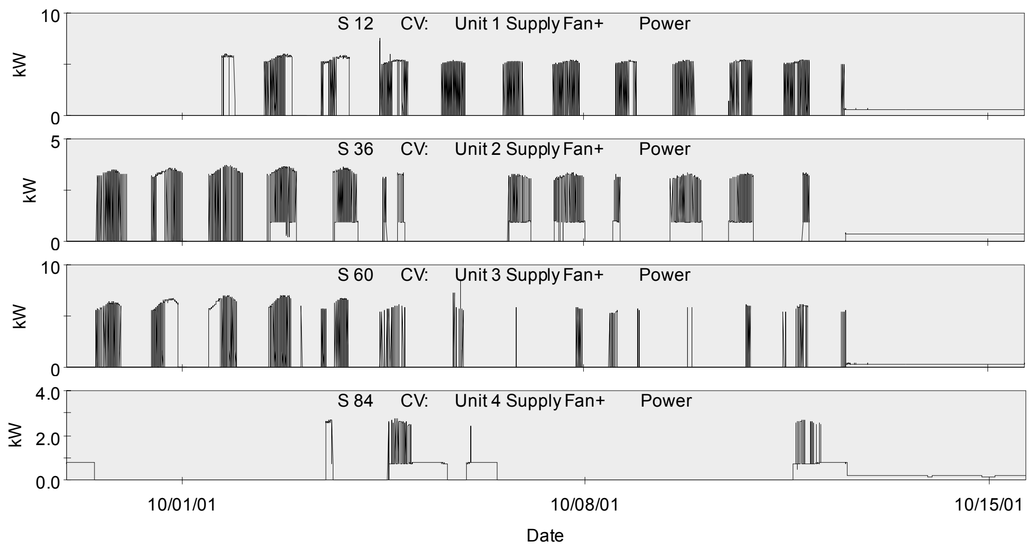
None of the units monitored had economizers.

Fan Schedules

The units do not appear to follow an on/off schedule. They run at varying times of the day every day of the week.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit Power vs. Time



Fan Operation

The supply fan in units NGGM092878 and NHGM096500 cycled with calls for cooling. The supply fans in units NGGM092876 and NHGM095852 cycled independently of the compressor, but did not appear to follow a specific schedule.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during milder months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Other Issues

The supply air temperature for unit NGGM092876 is above 60 degrees F; most units have a supply air between 50 and 55 degrees F. This may be representative of a refrigerant charge problem.

Site 165 - Swan Market

The Swan Market is a mixed use, commercial/residential group of buildings in downtown Oakland. The offices at Swan Market, 538 9th St. comprises approximately 15,000 square feet of conditioned space on the second floor of an historic building on the corner of 9th and Washington. Heating and cooling for the building is provided by Carrier packaged air conditioners. All units are equipped with single point enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on three of the units at this site. The units are identified by the following serial numbers: 110063005J, 1200G20953, and 0500630757.

Economizer Operation

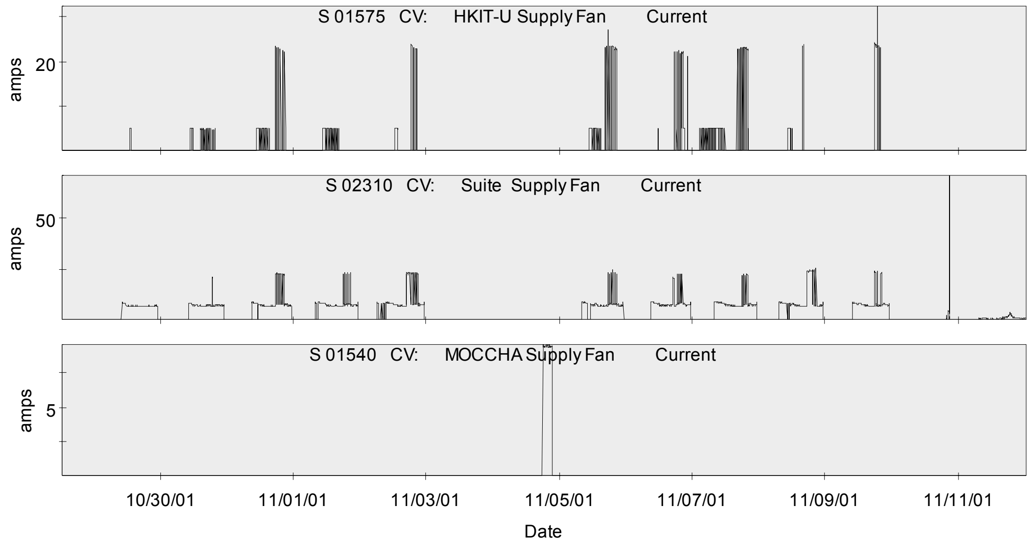
The economizers on three of the four units failed to operate during the monitoring period. Only one them showed a response to changes in climatic conditions.

Fan Schedules

The units appear to follow a Monday through Friday operation schedule. The units did not run at night or during the weekend during the monitoring period.

This figure displays the current for each of the units over time. Each series of data (from top to bottom) represents a different unit. The current is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit Power vs. Time



Fan Operation

The supply fan in units 110063005J and 0500630757 cycled with the compressor. The supply fan in unit 1200G20953 ran continuously when the building was occupied and remained off the rest of the time.

Simultaneous Heating and Cooling

During the monitoring period all of the units had the opportunity to run in both heating and cooling mode. No simultaneous heating and cooling occurred.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were of varying conditions and appeared to be maintained by different contractors. Some units appeared to be regularly serviced and others were in need of a filter change. Special attention should be paid to the filters, given that the exhaust of a downstairs kitchen is near the intake of several of these units.

Site 166 - Lawrence Family Jewish Community Center

The Lawrence Family Jewish Community Center in San Diego is a 98,000 square foot building. The area of the building conditioned by small packaged HVAC equipment is 6,212 square feet. Heating and cooling for the building is provided by Carrier packaged air conditioners.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 1599G30317, 1599G20458, 1599G20363, and 1599G20535. The on-site numbers for these units are AC2.17, AC1.12, AC1.10, and AC1.08 respectively.

Economizer Operation

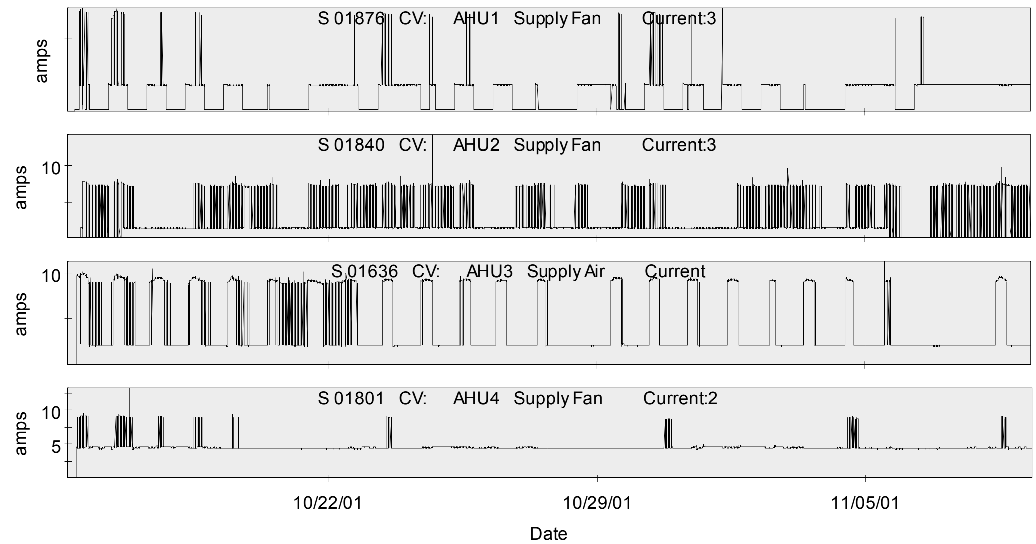
Unit 1599G30317 is equipped with a single point enthalpy economizer. The economizer modulated appropriately to provide cooling to the building during the monitoring period. None of the other units have economizers.

Fan Schedules

The supply fan in unit 1599G30317 cycled daily during the monitoring period. The supply fans in the other three units ran continuously.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit Power vs. Time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during milder months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 168 - National Steinbeck Center

The National Steinbeck Center at 1 Main Street in Salinas is a 38,000 square foot building. Heating and cooling for all 38,000 square feet of the space is provided by Trane packaged air conditioners. All of the units are equipped with differential temperature economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following numbers: AC-6, AC-5, AC-1 and AC-3.

Economizer Operations

The economizers in units AC-6 and AC-1failed to modulate during the monitoring period. The economizers in AC-3 and AC-5 did modulate, but it did not respond optimally to climatic changes.

Fan Schedules

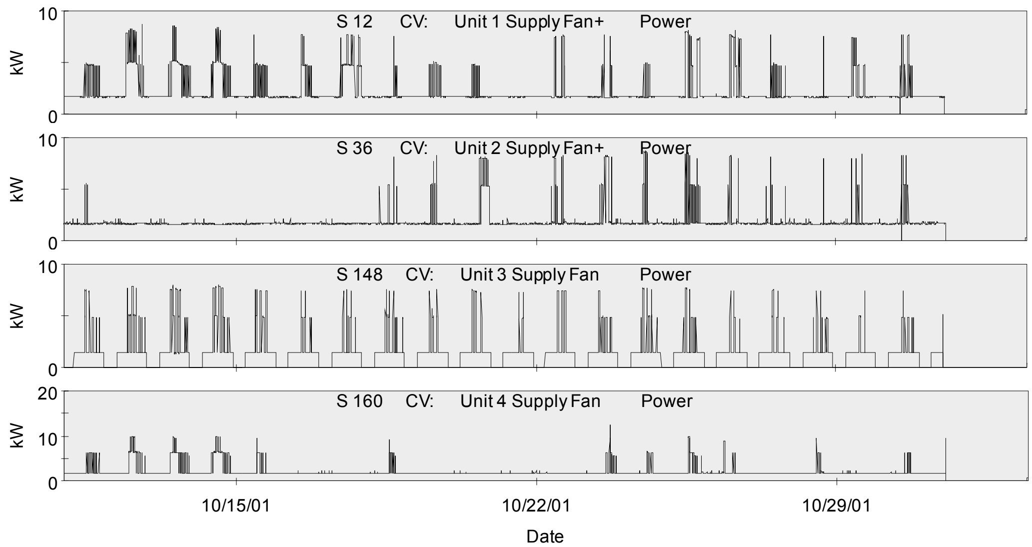
The supply fans in all of the units operate independently of calls for cooling. This allows fresh air to circulate through the building.

Fan Operation

The supply fan in AC-1 cycled daily with the occupancy of the building. The supply fans in the other three units remained on continuously during the monitoring period.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Supply Fan Power vs. Time



Simultaneous Heating and Cooling

During the monitoring period all of the units operated in both cooling and heating mode. No simultaneous heating and cooling occurred.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained. The new service contractor was on-site during the survey and mentioned he serviced the units recently.

Site 169 - Monrovian Family Restaurant

The Monrovian Family Restaurant at 534 Myrtle Ave in Monrovia is a two-story 10,490 square foot building. The majority of the space is conditioned and is used as a full service restaurant. Heating and cooling for the building is provided by Carrier packaged air conditioners. None of the units are equipped with economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on two of the units at this site. The units are classified by the following serial numbers: 3596G21111 and 2195G20925.

Economizer Operation

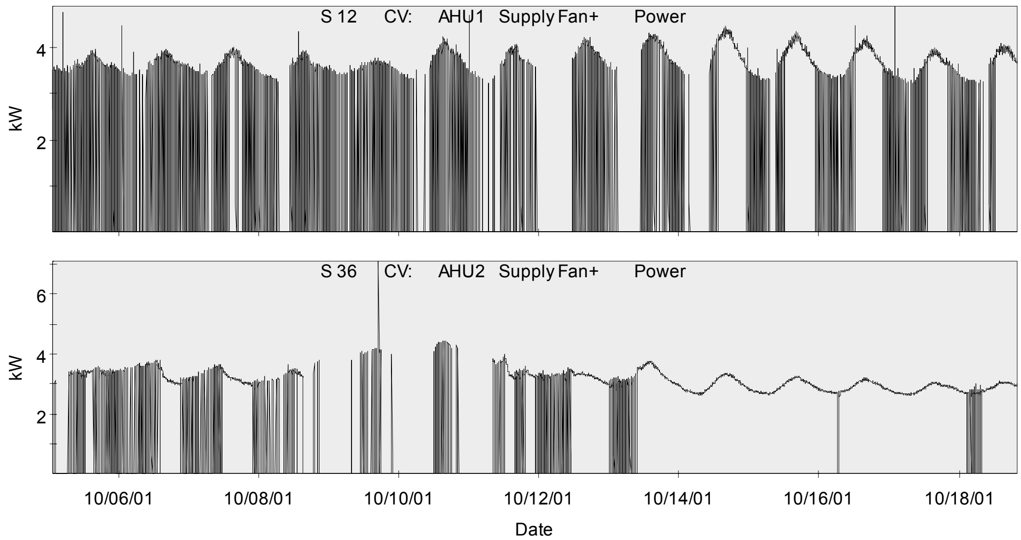
The units monitored did not have economizers.

Fan Schedules

Neither of the units appeared to follow an operation schedule. The units ran at all hours every day of the week. The compressor in unit 2195G20925 ran continuously for four days during the monitoring period.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit Power vs. Time



Fan Operation

The supply fan in each of the units monitored cycled with calls for cooling. The fans should run independently of the compressor to supply continuous fresh air to the building. The thermostats that are currently installed in the building are intended for residential use and are incapable of scheduling the fan operation independently of the compressor.

Simultaneous Heating and Cooling

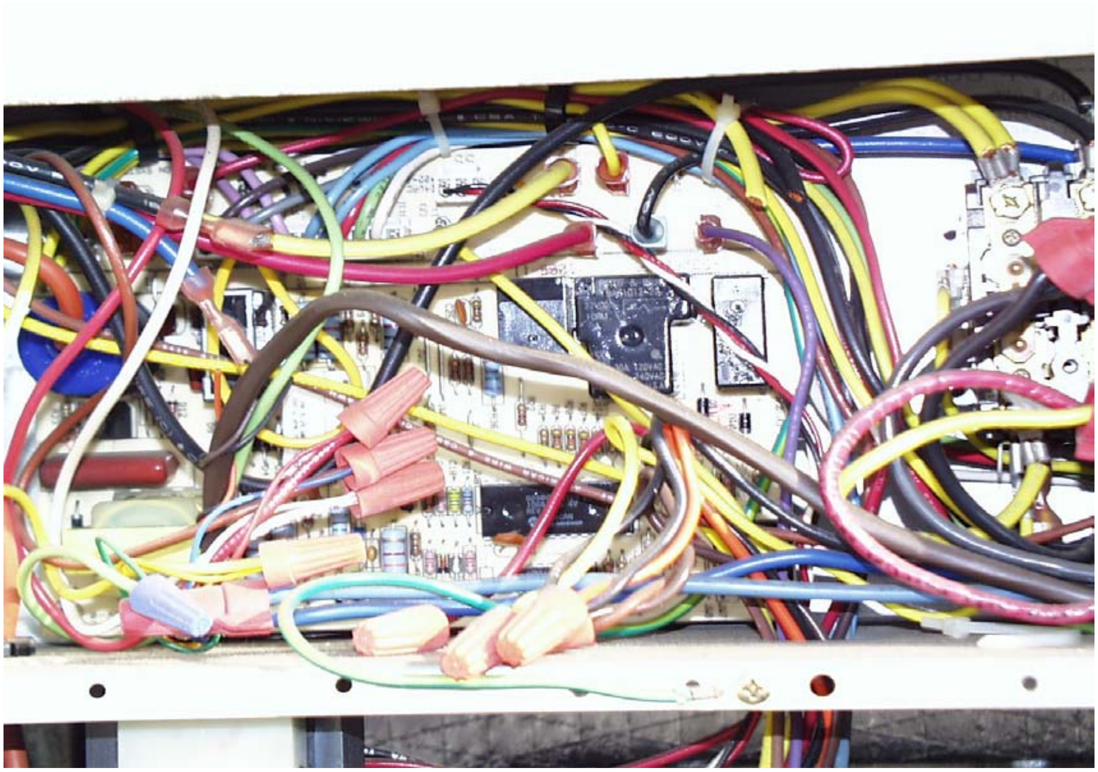
During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during milder months.

Maintenance Condition

The units appear to need servicing and cleaning. The grease in the exhaust air from the kitchen has clogged many of the filters, hindering the ability of the units to function properly. The following image shows the grease build-up on the exterior of one of the units:

Grease-Clogged Equipment

It was noted during the site visit that it was not possible to access many of the units for monitoring. In some cases, access panels were welded on. The wiring of one of the units was unsafe for testing because of poor installation.



Poor Wiring Installation

Other Issues

At the time of the site visit, one of the cooling coils had frozen up enough that ice was built up on the air filter. The supply air temperature in both of the units monitored was over 60 degrees F. At the time of the site visit in October the team of surveyors was unable to get two of the units to run. It is likely that there is something malfunctioning in these units.

Frozen Dirty Filter

There is a large amount of exposed ductwork on the roof of the building. The supply air temperature will significantly increase during the summer and decrease during the winter as a result of the heat transfer through the exterior of the ducts.

Site 172 - Bernice Ayar Elementary School

Bernice Ayar Elementary School at 1281 Via Sarmentoso in San Clemente is 19,720 square foot building. The portion of the school conditioned by small packaged HVAC equipment totals 6,216 square feet. Heating and cooling for the building is provided by Trane packaged air conditioners.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: M201043680, N18100503D, N18100504D, and N18100504D. The on-site numbers for these units are AC-7A, AC-6A, AC-12A, and AC-5A respectively.

Economizer Operations

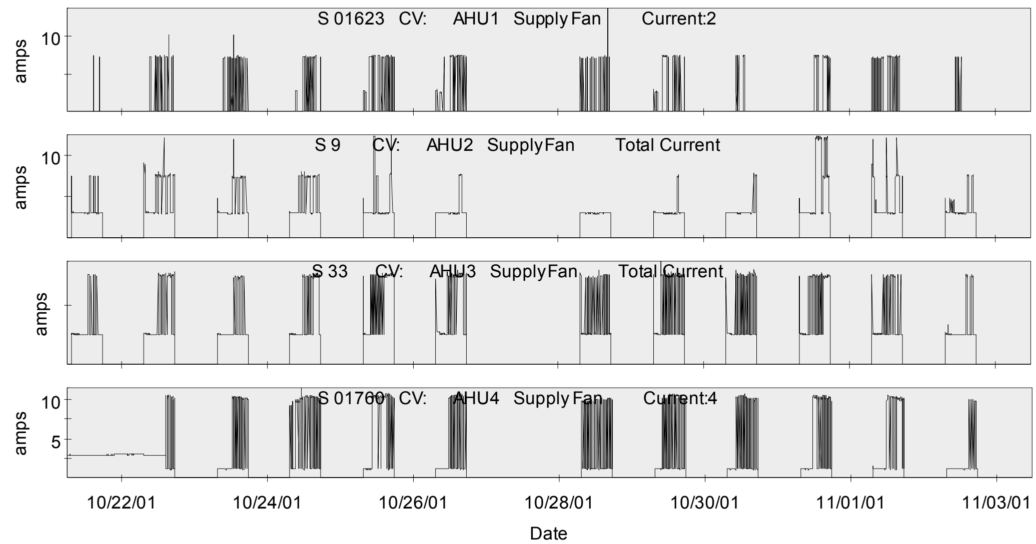
The results of diagnostic monitoring show that the economizer dampers did not modulate in three of the four units tested.

Fan Schedules

In all of the units the supply fans cycled daily with the occupancy schedule of the building.

This figure displays the kW for each of the units over time. Each series of data (from top to bottom) represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit Power vs. Time



Fan Operation

The supply fans in all of the units cycled independently of the compressors. This allows outside air to circulate continuously through the building.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during milder months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained. At the time of the site visit maintenance staff were onsite servicing the units.

Site 175 - Huntington Seacliff Elementary School

Huntington Seacliff Elementary School at 6701 Garfield Ave in Huntington Beach is a multiple building facility. This document focuses on the characteristics of the 8,316 square foot administration and library building. Heating and cooling for the building is provided by Trane packaged air conditioners.

Monitoring Configuration

Short term diagnostic monitoring was performed on three of the units at this site. The units are classified by the following serial numbers: P261011338D, P26100993D and P26100964D. No numbers could be found on the units at the time of the site visit.

Economizer Operations

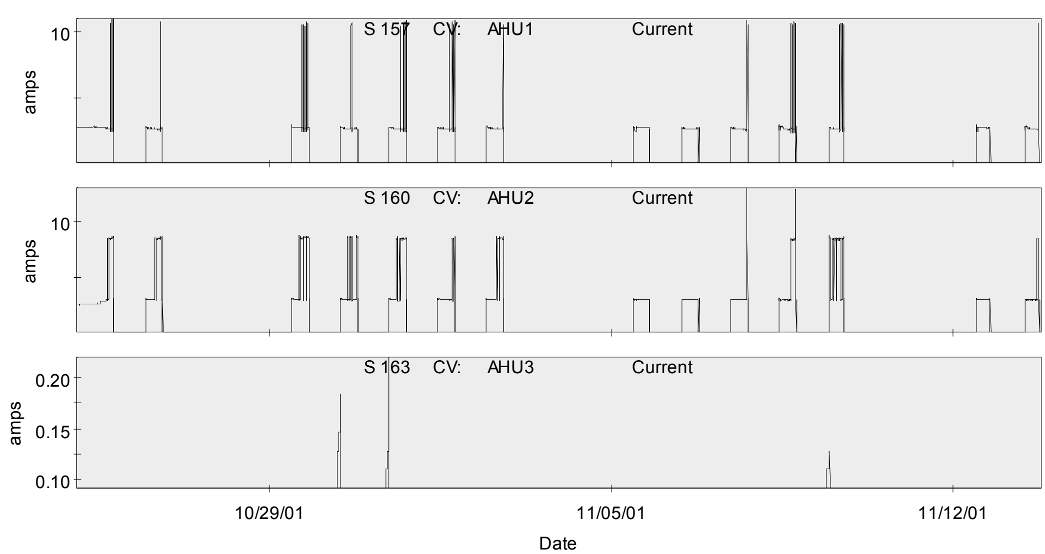
Unit P261011338D is equipped with an economizer. The results of diagnostic monitoring show that the economizer dampers in this unit did not modulate in response to changes in climatic conditions during the monitoring period.

Fan Schedules

The supply fans in all of the units followed the occupancy schedule of the building.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit Current vs. Time



Fan Operation

In each unit monitored the supply air fan did not cycle with calls for cooling. This allows outside air to circulate continuously through the building.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Other Issues

The supply air temperature in unit P26100993D is consistently over 60 degrees. This is indicative of a potential refrigerant charge problem.

Site 176 - U.S. Department of Agriculture

The Department of Agriculture offices at 11840 South Cienga Blvd. is a 12,208 square foot building. Conditioned office space consumes 11,048 of the building; the remainder is used for unconditioned storage. Heating and cooling for the building is provided by Carrier packaged air conditioners.

Monitoring Configuration

Short term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 2199G20163, 1599G43301, 2199G20167 and 3199G43240.

Economizer Operation

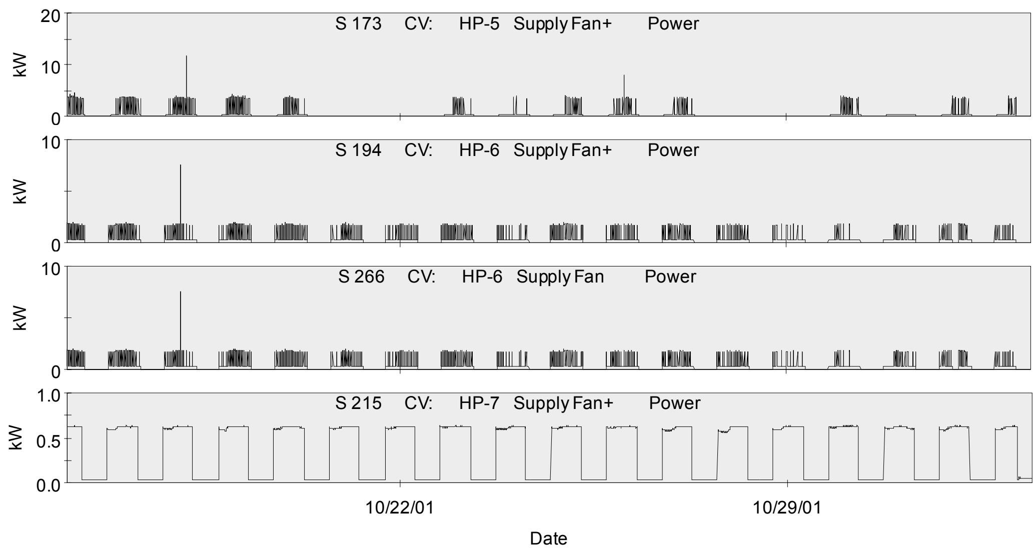
None of the units surveyed had economizers.

Fan Schedules

The supply fans in all of the units respond appropriately to the schedule of the building. The supply air fans allow fresh air to circulate during the occupied period and remains off when the building is unoccupied.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan cycled independently of the compressors as intended.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 186 - Rio Calaveras Elementary School

Rio Calaveras Elementary School, 1515 Bianchi Road in Stockton is a 36,482 square foot building. Heating and cooling for the building is provided by Trane packaged air conditioners. All of the units are equipped with differential temperature economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: N121023810, N12102384N, N12102383D and N12102410A. The on site numbers for these units are AC-3, AC-4 AC-5 and AC-7 respectively.

Economizer Operations

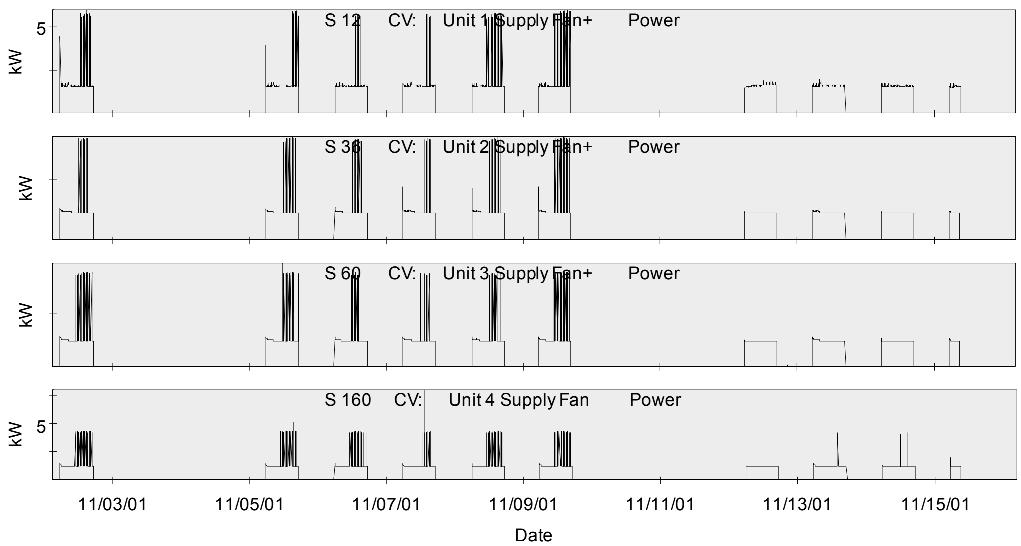
The results of diagnostic monitoring show that the economizer dampers did not modulate in three of the four units during the monitoring period.

Fan Schedules

The supply fans follow the building use schedule. The supply air fans circulate fresh air during the occupied period and remain off when the building is unoccupied.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling.

Simultaneous Heating and Cooling

During the monitoring period all of the units operated in heating and cooling mode. The units generally provided heat to the space in the morning and cold air in the afternoons. No simultaneous heating and cooling occurred.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 238 - Babies “R” Us, Brea, California

The Babies “R” Us store at 2575 East Imperial Highway in Brea is a single-story, 38,614 square foot building. The majority of the space is conditioned and used for retail sales, while the remainder is used for unconditioned storage.

Various 11-ton Lennox packaged air conditioners provide heating and cooling for the building. All of the units are equipped with differential enthalpy economizers that modulate outside air proportions and provide free cooling when conditions permit. The HVAC system is controlled by a NOVAR energy management and control system.

Short term diagnostic monitoring was performed on four of the rooftop units at this site. The units are classified by the following names, which can be found on the outside of each unit: AC-1, AC-2, AC-3 and AC-4.

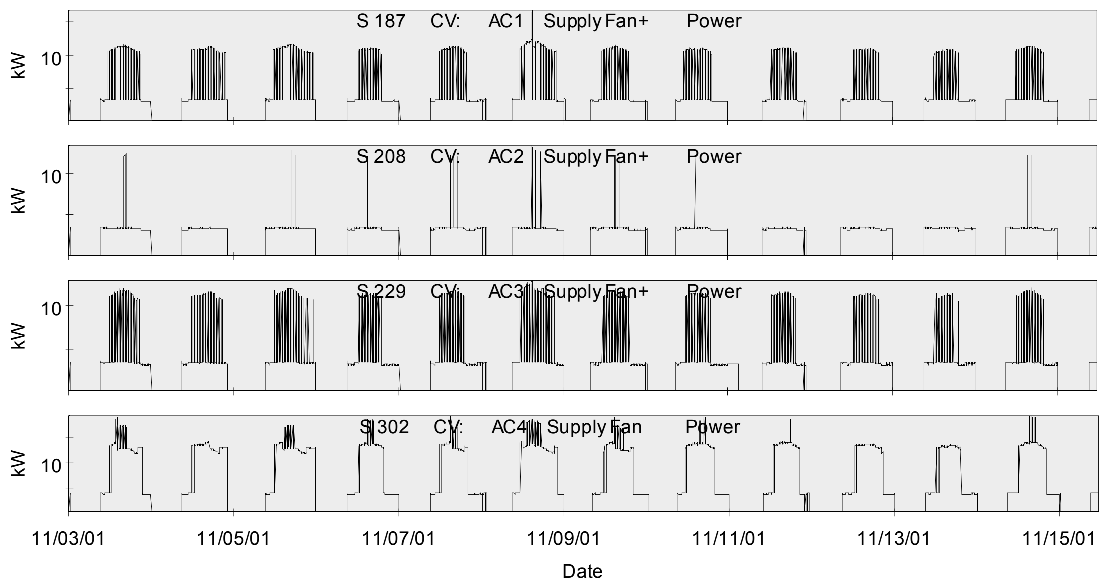
Fan Schedules

The NOVAR energy management system installed in the building is responding appropriately to the schedule of the building. The supply air fans allow fresh air to circulate during the occupied period and remain off when the building is unoccupied.

Fan Operation

In each unit, the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling. The following plot shows the operation of the units over the two-week monitoring period. Fan only operation uses about four kW of power in each of the units, first stage cooling uses 10kW and demand spikes above 10 kW represent second stage cooling.

Time series plot of unit kW



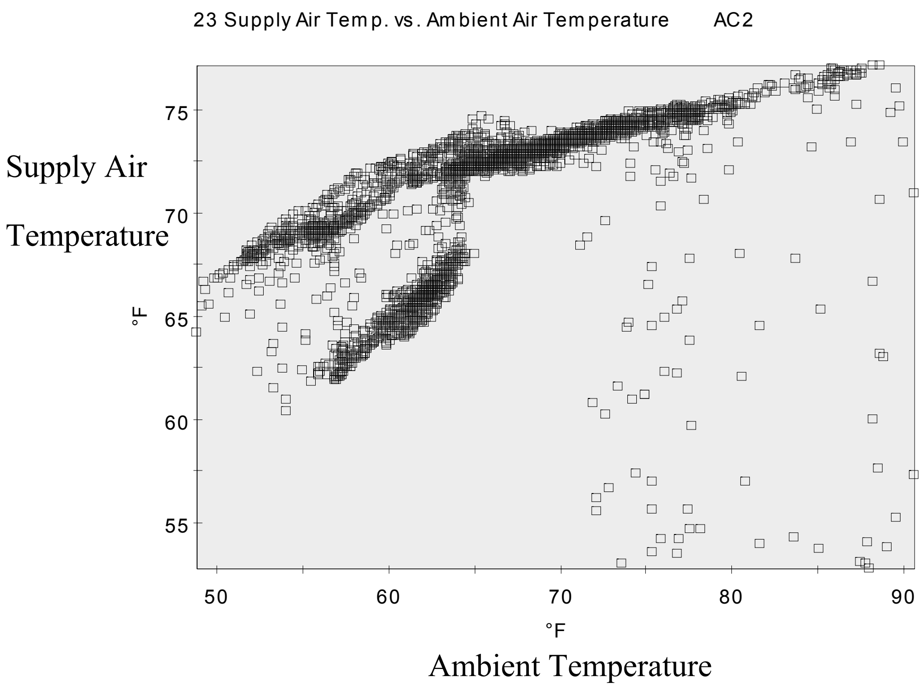
Maintenance Condition

All of the units appeared to be in good operating condition. The filters in the units are clean and it appears that the units are regularly serviced and maintained.

Other Issues

Diagnostic monitoring shows that the supply air temperature for AC-2 averages 62 degrees. This is slightly higher than the desired 55 to 60-degree range. This may be indicative of a mechanical problem with the HVAC unit.

AC-2 supply air temperature vs. outdoor temperature, filtered by compressor operation.

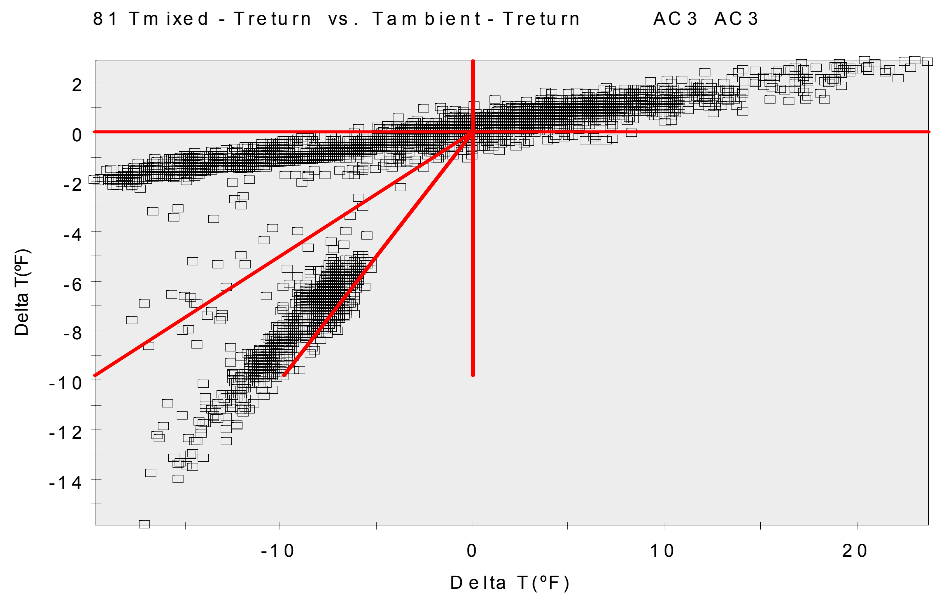


Suggestion to Adjust Economizer to Operate Properly

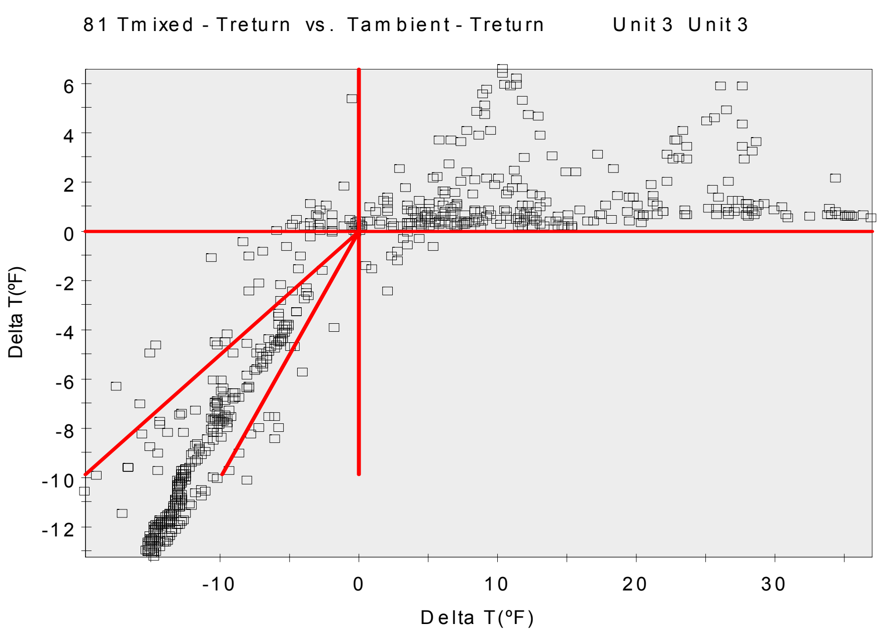
The results of diagnostic monitoring show that the economizer dampers did modulate during the monitoring period. The economizer dampers on all of the units, however, did not modulate optimally in response to the outside conditions. At times, outside air temperatures were low enough to cool the building with outdoor air. However, cooling for the building was provided mechanically, resulting in higher operating costs than if the economizers were used.

The data indicates that outside air temperatures were low enough at times to cool the building with outdoor air.

Babies "R" Us economizer operation



Example of functioning economizer operation.



Site 244 - Rite-Aid Hesperia

The Rite-Aid at 17441 Main Street in Hesperia is a 17,400 square foot building. The majority of the space is conditioned and used for retail sales, while the remainder is used for unconditioned storage. Heating and cooling for the building is provided by York packaged air conditioners. All of the units are equipped with single-point enthalpy economizers, which modulate outside air proportions and provide free cooling when conditions permit.

Monitoring Configuration

Short-term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: NLGM138216, NLGM138214, NLGM138217, and NLGM138215. The on site numbers for these units are AC-1, AC-2, AC-3, and AC-4 respectively.

Economizer Operations

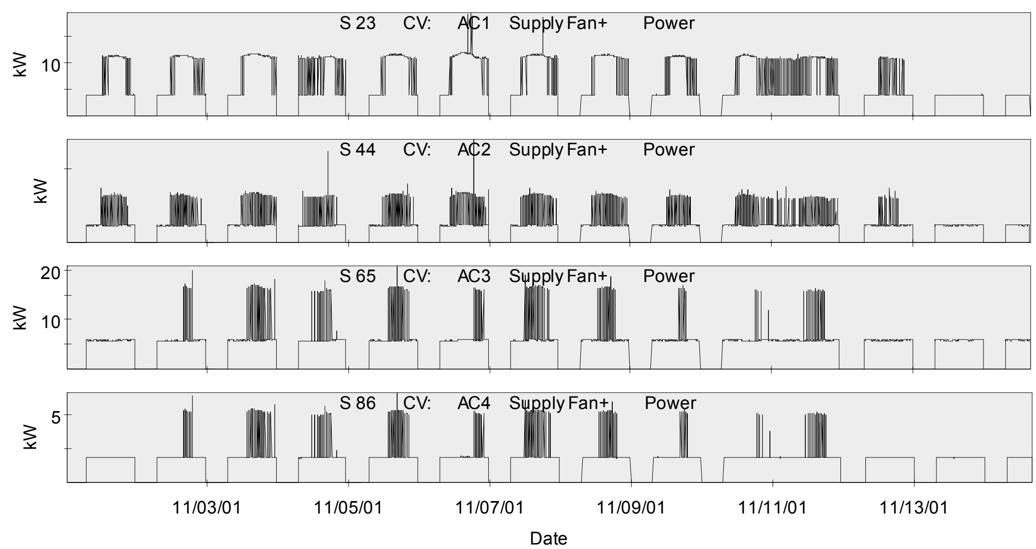
The results of diagnostic monitoring show that the economizer dampers did not modulate appropriately in response to climate conditions during the monitoring period.

Fan Schedules

The operation of the units monitored follows the schedule of the building. The units remain off at night when the building is scheduled as unoccupied.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

In each unit monitored the supply air fan remained on during the occupied period as intended and did not cycle with calls for cooling. Continuous operation of the supply air fans allows for required ventilation of the building.

Simultaneous Heating and Cooling

During the monitoring period none of the units operated in heating mode. It is possible that simultaneous heating and cooling may occur during the more mild months.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 250 - American Canyon Middle School

American Canyon Middle School, at 300 Benton Way in American Canyon is a 38,500 square foot middle school. Heating and cooling for 12,580 square feet of the building is provided by Carrier rooftop packaged air conditioners.

Monitoring Configuration

Short term diagnostic monitoring was performed on four of the units at this site. The units are classified by the following serial numbers: 2897G20668, 3397G31021, 2797G20555, and 3397G31019.

Economizer Operation

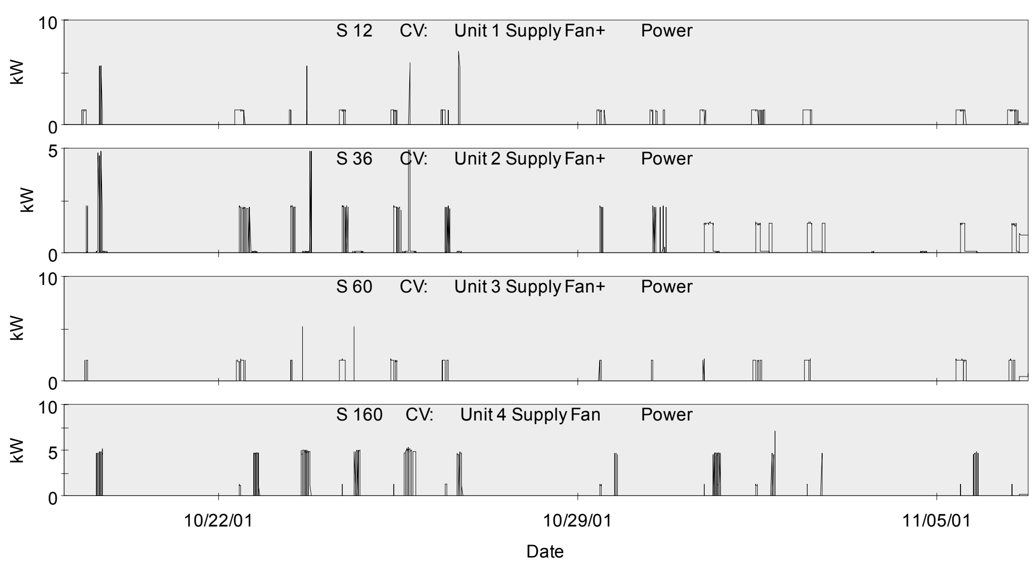
None of the units monitored had economizers. An economizer controls the amount of outside air that enters the unit and can provide "free cooling" to a space when the outside temperature permits.

Fan Schedules

In each unit monitored the supply air fans did not remain on during the entire occupied period. It appears that the supply fans are not scheduled correctly to match the building use schedule.

This figure displays the kW for each of the units over time. Each series of data, from top to bottom represents a different unit. The kW is labeled to the left of each time series plot. The date and time are labeled at the bottom. Each unit is labeled in the center of the top of each series.

Unit power vs. time



Fan Operation

The supply air fans circulate fresh air during the occupied period and remain off when the building is unoccupied.

Simultaneous Heating and Cooling

During the monitoring period all of the units had the opportunity to run in both heating and cooling mode. No simultaneous heating and cooling occurred.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained. A quarter inch hole was observed on the exterior supply air duct of the unit that serves the library. It is recommended that this hole be patched.

Other Issues

Two buildings were studied at this site, the Library and the Main Office. At each of these locations the rooftop units were zoned incorrectly. Each building had two units, one larger and one smaller, with two corresponding zones. The larger units were both connected to the smaller of the two zones, serving the northeast portion of the buildings, while the smaller units served the larger southwest portions of the buildings. The problem was identified by disabling one unit at each building while forcing the other unit to run continuously. While each unit ran the diffusers were checked for airflow to determine which unit served each zone. The units were also mislabeled; it appeared that the installer intended to have the units configured correctly because the handwritten labels on the units reflect the appropriate configuration.

2 ROUND 2 SITES

The results of the round 2 testing are described in this section. The diagnostic testing process used in Round 2 included on-site auditing of the building and one-time tests of the HVAC systems. During the on-site audit, a sample of HVAC units was selected for study. Building personnel were interviewed to obtain an understanding of system operations and maintenance procedures. The thermostats used to control the units were inspected to identify cooling and heating setpoints, the operational schedule of the unit, and the control of the air supply fan.

Spot-checking of the HVAC equipment selected with hand-held instruments was done to identify potential problems with the units. The diagnostic testing consisted of:

Air flow monitoring. The air flow rate of the unit was tested using a device called a flow grid. The unit filters were removed, and the flow grids were installed in the filter slots. The flow grid is capable of accurately measuring the air flow rate delivered by the unit.

Economizer testing. For units equipped with an economizer, the economizer was tested to see if it is functioning. The testing consisted of a mechanical test of the economizer dampers and actuators, and a cold spray test of the economizer controller to observe system operation.

Fan power test. A hand-held watt meter was used to measure the power of the unit supply fan, and a digital manometer was used to measure the duct system pressure drop.

Refrigerant charge test. The refrigerant charge was checked and adjusted using the CheckMe!™ [1] refrigerant charge diagnostics procedure.

The conditions of the units as observed are summarized in the following sections. Deviations from normal conditions are indicated for the measured parameters. Impacts indicated with a negative sign mean the unit is less efficient than normal parameters. Impacts with a positive sign indicate the unit is more efficient than normal parameters.

Unit air flow: Normal air flow is defined as 400 CFM per ton. The impacts of deviations from this value on unit cooling efficiency are indicated in the data tables.

Unit fan power. Normal fan power is defined as 365 watts per 1000 cfm, at a flow rate of 400 cfm per nominal ton. Impacts on fan energy are indicated in the data tables.

[1] CheckMe!™ is a product of Proctor Engineering Group, San Rafael, CA.

Site 170 IHOP

The IHOP at 3800 Northgate Boulevard in Sacramento is a single story 3,900 square foot building full service restaurant. Heating and cooling for the building is provided by one 4 ton and two 7.5 ton York packaged rooftop units, each equipped with an economizer. A photo of the building is shown in Figure 1.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1	York	D1EG090N13025ECE	7.5
RTU-2	York	D2EG048N06025	4

Unit Number	Make	Model Number	Cooling Capacity (tons)
RTU-3	York	D1EG090N13025ECE	7.5

Economizer Operation

None of the economizers tested at this site were operable.

Fan Schedules

Thermostat not capable of scheduling the fan. The fans in all units were scheduled on at all times regardless of occupancy.

Fan Operation

The fans operated continuously in all units.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling efficiency impact
AC-1	684	3,000	22.8%	22.0%
RTU-2	1,010	1,600	63.1%	14.6%
RTU-3	1,850	3,000	61.7%	15.4%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan efficiency impact
AC-1	406	1,095	63%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling efficiency impact
AC-1	Charge is OK	None
RTU-2	Charge is OK	None
RTU-3	Charge is OK	None

Maintenance Condition

The condition and apparent level of maintenance of each unit is shown below:

Unit	General condition
AC-1	Small air leakage around supply air cover. No filters installed. Dirty evaporator coils.
RTU-2	Fan belt loose. No filters installed, outdoor air adjustment not working; outdoor air damper stuck at 100% open.
RTU-3	Evaporator coils very dirty. System has run without filters for a very long time. Economizer actuator not functional. Condenser coils very dirty. Compressor 1 replaced recently, but was installed without vibration dampers.

Filthy filters and iced evaporator coil

Missing vibration dampers on recently replaced compressor

Other Issues

AC-1 outdoor air intake located adjacent to powered exhaust fan, as shown in photo below:

Building exhaust fan discharging directly into outdoor air intake

Site 174 - The Foundation for the Retarded of the Desert

The Foundation for the Retarded of the Desert at 73-256 Country Club Drive in Palm Desert is a single story 26,320 square foot building. Heating and cooling for the building is provided by nine packaged rooftop units. During periods of low humidity cooling to the work shop areas is supplied by evaporative coolers and the rooftop units are not used.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1	Trane	YCD091D4LOBE	7.5
AC-2	Trane	YCD091D4LOBE	7.5

Economizer Operation

Both of the units tested were equipped with economizers. The economizers passed both functional performance tests, indicated that they are working properly.

Fan Schedules

The fans are scheduled to come on during occupied periods and are scheduled off during unoccupied periods.

Fan Operation

Fan operation is intermittent during occupied periods.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-1	1,935	3,000	64.5%	-14.0%
AC-2	2,017	3,000	67.2%	-12.7%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impacts
AC-1	664	1,095	39%
AC-2	864	1,095	21%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency Impact
AC-1	Charge is OK	None
AC-2	Charge is OK	None

Maintenance Condition

The units appeared to be well maintained. Maintenance access on the two units tested was restricted, since the units were mounted within two feet of a parapet wall.

Site 185 – Walgreen's

The Walgreens at 5300 3rd Street in San Francisco is a single story 13,000 square foot building. Heating and cooling for the building is provided by Trane packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1	Trane	YCD091D4LABE	7.5
AC-3	Trane	YCD091D4LABE	7.5
AC-4	Trane	YCD091D4LABE	7.5
AC-5	Trane	YCD061C4LABF	5

Economizer Operation

All units tested were equipped with economizers. The economizer did not work on unit AC-3.

Fan Schedules

Fans were scheduled to run whenever there is a call for heating or cooling

Fan Operation

Fans cycle on a call for heating and cooling

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-3	2,890	3,000	96.3%	-2.8%
AC-4	2,704	3,000	90.1%	-5.7%
AC-5	1,977	2,000	98.9%	-1.0%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC-1	1401	1125	-28%
AC-3	1424	1125	-30%
AC-4	1324	1125	-21%
AC-5	739	750	-28%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency Impact
AC-1	-2.5%	-3.3%
AC-2	-2.0%	-3.0%
AC-3	4.9%	-0.3%
AC-4	4.7%	-0.3%

Maintenance Condition

Unit AC-2 had a bad Schrader valve that needs to be replaced. The filters were clean and the units seemed to be well-maintained.

Site 195 Manufacturing Complex

The Manufacturing Complex at 8382 Artesia Boulevard in Buena Park consists of four single story buildings comprising a total of 56,550 square feet. Building D was selected for study, and is conditioned by five packaged rooftop units.

Building D Entrance

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC2	York	B1HA024A06B	2
AC3	York	B1HA024A06B	2

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC4	York	B1HA024A06B	2

Economizer Operation

None of the units tested were equipped with economizers.

Fan Schedules

Fan operation is scheduled to follow the building occupancy schedule.

Fan Operation

The fans in units AC2 and AC3 cycle with a call for heating and cooling. The fan in unit AC4 runs continuously during occupied periods.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC2	707	800	88.4%	-6.3%
AC3	650	800	81.3%	-8.1%
AC4	1,065	800	133.1%	0.0%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC2	230	292	21%
AC3	231	292	21%
AC4	422	292	-45%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
AC2	9.4%	1.2%
AC3	Leaks	
AC4	Charge OK	No impact

Maintenance Condition

The units were in good condition and appeared to be well maintained.

Site 197 - Allure Home Creation Center Warehouse

The Allure Home Creation Center warehouse at 13365 Philadelphia Avenue in San Bernardino is a single story 266,000 building. Heating and cooling for the building is provided by two 3 ton and two 5 ton Carrier packaged rooftop heat pumps.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
RTU#1	Carrier	50TJQ006-601GA	5
Unit #3	Carrier	50TJQ004---601GA	3
Unit #4	Carrier	50TJQ004---601GA	3

Unit Number	Make	Model Number	Cooling Capacity (tons)
Unit#2	Carrier	50TJQ006---601GA	5

Economizer Operation

None of the units at this site were equipped with economizers.

Fan Schedules

The units were scheduled to run 24 hours/day, 7 days/week, while the building is occupied 6am to 6pm Monday-Friday.

Fan Operation

The fans are set up to run continuously.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
RTU#1	1,190	2,000	59.5%	16.5%
Unit #3	924	1,200	77.0%	9.2%
Unit #4	990	1,200	82.5%	7.8%
Unit#2	1,290	2,000	64.5%	14.0%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

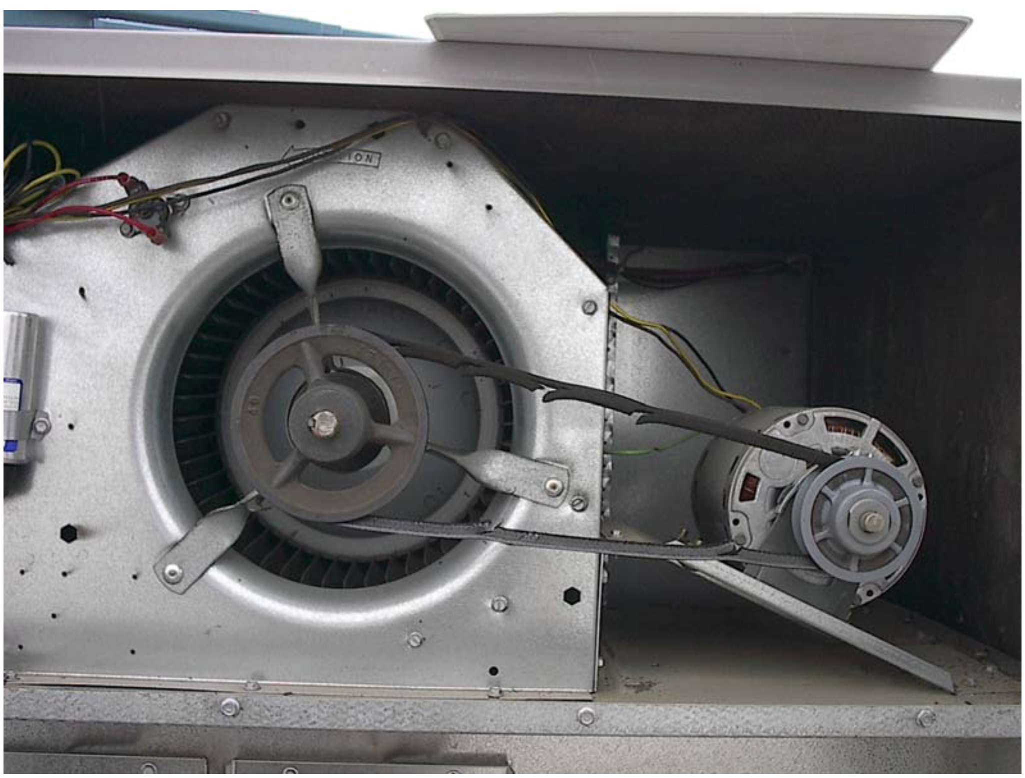
Unit	Measured Watts	Normal Watts	Fan efficiency Impact
RTU#1	560	730	23%
Unit #3	401	438	8%
Unit #4	445	438	-2%
Unit#2	650	730	11%

Refrigerant Charge

The units were installed with a incompatible curb, allowing supply air to short circuit into the returns. It was not possible to conduct the refrigerant test because the return air temperature was too low for the test procedure.

Maintenance Condition

Units were in average condition. Unit 4 had a severely worn fan belt:



Other Issues

The units were installed with an incompatible curb, allowing supply air to short circuit into the returns, as shown below:

Misalignment of unit supply and return outlets with building ductwork

Close-up of unit supply plenum showing bypass into return side

Site 198 - Chevron Gas Station/Food Mart

The Chevron Gas Station/Food Mart at 1009 E. Pacheco Boulevard in Los Banos is a single story 3,200 square foot building. Heating and cooling for the building is provided by one 3 ton and one 5 ton Bryant packaged rooftop unit.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC1	Bryant	501BPU031072APAA	3
AC2	Bryant	581PU060072ADAA	5

Economizer Operation

Neither unit at this site was equipped with an economizer

Fan Schedules

The fans are scheduled to operate along with the building occupancy, which is 24 hours per day, 7 days per week.

Fan Operation

The fans are set up to cycle on and off with a call for heating or cooling.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC1	872	1,200	72.7%	-10.6%
AC2	1,307	2,000	65.4%	-13.6%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC1	380	438	13%
AC2	740	730	-1%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
AC-1	Charge OK	No Impact
AC-2	Charge OK	No Impact

Maintenance Condition

The filters and coils were very dirty at this site.

Filter as removed from system

Indoor coil dirty and showing signs of corrosion.

Other Issues

There was no outdoor air intake for unit AC-1.

Site 207 - Office Building

The Office Building at 3586 4th Avenue in San Diego is a three story 6,420 square foot building. Heating and cooling for the building is provided by two Carrier 4 ton packaged rooftop heat pumps.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1	Carrier	50TJQ005	4
AC-2	Carrier	50TJQ005	4

Economizer Operation

Economizers were not installed at this site

Fan Schedules

The fans are scheduled on between 7:30am and 5 pm. The building is occupied between 8am and 5pm.

Fan Operation

The fans were set up to cycle on a call for heating in cooling during occupied hours in both units.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-1	1,840	1,600	115.0%	0.0%
AC-2	1,495	1,600	93.4%	-4.4%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC-1	870	584	-49%
AC-2	621	584	-6%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
AC-1	-9.57%	-9.0%
AC-2	-9.57%	-9.0%

Maintenance Condition

Units were in good condition.

Site 211 - Sunsports

Sunsports is a single story 500,000 square foot building, consisting of conditioned office space and unconditioned storage space. Heating and cooling for the conditioned portion of the building is provided by three packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1	Trane	WCD090C400BC	7.5
AC-3	Carrier	50TJQ005	4

Economizer Operation

Unit AC-1 was equipped with an economizer, which did not respond to the cold spray test. Unit AC-3 was not equipped with an economizer.

Fan Schedules

The building is occupied between 7 am and 10 pm Monday through Friday, and 8am to 1 pm on Saturday. The fans are set to run whenever there is a call for heating or cooling. The thermostat for unit AC-1 is set to comfort conditions from 6am to 10pm; the thermostat for unit AC-3 is set for comfort conditions from 6am to 6:30pm.

Fan Operation

The fans are set up to cycle on a call for heating or cooling.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-1	2076	3000	-30.8%	-11.9%
AC-3	1364	1600	-14.8%	-7.1%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan efficiency impact
AC-1	742	1,095	32%
AC-3	704	584	-21%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
AC-1	4.37%	0.1%
AC-2	-7.29%	-6.8%

Maintenance Condition

Unit AC-1 had bent condenser fan blades and a missing wire on the control board. Maintenance access was poor due to materials blocking access to roof hatch ladder.

Site 213 - Mediaworks

Mediaworks at 12910 West Culver Boulevard in Los Angeles is a two-story 80,000 square foot building. Heating and cooling for the building is provided by Lennox packaged rooftop units

Testing Configuration

Diagnostic testing was performed on the following unit at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC30	Lennox	LGA120SH19	10

Economizer Operation

The unit tested at this site was not equipped with an economizer. The unit also did not have any provision for bringing in outside air, but building had operable windows.

Fan Schedules

The fan schedule follows the occupancy schedule, which is 8am to 5pm M-F. The fans are schedule off during the unoccupied period

Fan Operation

Fans are set up to run continuously during the occupied period.

Unit Air Flow

The air flow rates for the unit tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC30	3,117	4,000	77.9%	-9%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Watts per CFM	Fan Efficiency Impact
AC30	1,607	1,460	-10%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Efficiency impact
AC30	12.2%	-4.7%

Maintenance Condition

Units were in good condition. The duct system had balance problems, which were corrected by the occupants using bubble wrap to block air flow from several diffusers.

Site 216 Geico Regional HQ Building

Geico Regional HQ Building Phase II at 14111 Danielson Street in Poway is a two-story 145,000 square foot building. Heating and cooling for the building is provided by a combination of rooftop units and central chiller plant.

Testing Configuration

Diagnostic testing was performed on the following unit at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
RTU-09	Carrier	50TJQ006	5

Economizer Operation

The economizer on this unit was mechanically operable, but did not respond to the cold spray test.

Fan Schedules

The fans follow the occupancy schedule, which is 8am to 4:30pm.

Fan Operation

The fan is set up to cycle with a call for heating or cooling.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
RTU-09	1,437	2,000	71.9%	-10.9%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
RTU-09	670	730	8%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency Impact
RTU-09	-4.69%	-4.7%

Maintenance Condition

The unit was in average condition, indicating adequate maintenance.

Site 245 - Staples

Staples at 44620 Valley Central Way in Lancaster is a single story 24,000 square foot building. Heating and cooling for the building is provided by nine packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC12	Carrier	48DJD008530	7.5
AC-1	Carrier	48LJE006520	5
ETM-7	Carrier	48DJB012530	10

Economizer Operation

Two of the three units tested had economizers, but one was disconnected.

Fan Schedules

Units are controlled by Novar EMS, which controls fans according to occupancy schedule. Occupancy schedule is Mon-Sat 9am - 9pm, Sun 9am - 7 pm.

Fan Operation

EMS controls fans to operate continuously during occupied periods.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC12	2,565	3,000	85.5%	-7.1%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Watts per CFM	Fan Efficiency Impact
AC12	1,448	1,095	-32%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency Impact
AC-12	Major leak – no measurements possible	N/A

Maintenance Condition

All units had very dirty filters. Economizers were disconnected in two of three units examined. Unit AC-12 had a major refrigerant leak.

Site 259 - Albertson's

The Albertson's at 232 Dyer St. in Union City is a single story 65,000 square foot building. Heating and cooling for the building is provided by two 3 ton and one 5 ton Trane packaged rooftop units along with air handlers served by refrigeration racks.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
RTU-1	Trane	YCD060C4LC13F	5
RTU-2	Trane	YCD036C4LGBE	3
RTU-3	Trane	YCD036C4LGBE	3

Economizer Operation

All three units were equipped with economizers. One unit had stuck linkage; the others responded appropriately.

Fan Schedules

All fans controlled by central office through store EMS.

Fan Operation

Fans were set to operate continuously during occupied periods.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
RTU-1	1,702	2,000	85.1%	-7.2%
RTU-2	820	1,200	68.3%	-12.2%

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
RTU-3	960	1,200	80.0%	-8.4%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
RTU-1	1,008	730	-38%
RTU-2	325	438	26%
RTU-3	293	438	33%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
RTU-1	Charge OK	No Impact
RTU-2	Charge OK	No Impact
RTU-3	Charge OK	No Impact

Maintenance Condition

Filters were dirty during site visit. Units appeared to be in average condition.

Site 261 - North Canyon Business Center

The North Canyon Business Center at 3025-3095 Independence Drive in Livermore is a single story, multi building complex totaling 100,000 square foot. Heating and cooling for the building examined is provided by five 10 ton and one 7.5 ton Byrant packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1	Bryant	580DEU120180ACAA	10
AC-2	Bryant	580DEV120180ACAA	10

Economizer Operation

Both units tested were equipped with economizers. Unit AC-1 had operable linkage but did not respond to the cold spray test. Unit AC-2 had inoperable linkage.

Fan Schedules

Thermostats are set up to operate fans from 6am to 8pm, 7 days per week. Building is unoccupied.

Fan Operation

Fans are set up to run continuously during the occupied period.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-1	3,611	4,000	90.3%	-5.7%
AC-2	3,310	4,000	82.8%	-7.8%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency Impact
AC-2	Charge OK	No impact

Maintenance Condition

Units were observed to be in average condition. Insulation was loose on filter access panel of AC-1.

Site 265 - Fire Station #5, General Description

Fire Station #5 at 9130 Carlton Oaks Drive in Santee is a single story 8,108 square foot building. Heating and cooling for the building is provided by two York packaged rooftop units and two split system air conditioners.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1	York	D7CG060N07925DBA	5
AC-2	York	D2CG072N0792SEBA	6

Economizer Operation

Both units tested were equipped with economizers. The economizer on unit AC-2 failed the cold spray test.

Fan Schedules

The units tested serve the sleeping and living areas of the fire station, which are occupied 24 hrs/day; 7 days/week. The fans are scheduled on at all times.

Fan Operation

The fans in both units are set up to cycle on and off with a call for heating or cooling.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-1	1,626	2,000	81.3%	-8.1%
AC-2	1,173	2,400	48.9%	-22.0%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC-1	910	730	-25%
AC-2	510	876	42%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency Impact
AC-1	Charge OK	No Impact
AC-2	Charge OK	No Impact

Maintenance Condition

Units were observed to be in good condition.

Site 268 - True Hope of God in Christ Church

The True Hope of God in Christ Church at 950 Gilman Avenue in San Francisco is a single story 15,500 square foot building. Heating and cooling for the building is provided by five packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1	Trane	YCD06DC3LOBT	5
RTU-2	Carrier	48TJF008	7.5

Economizer Operation

Both units tested were equipped with economizers. The economizer on unit RTU-2 was functioning, the economizer on unit AC-1 functioned mechanically but failed the cold spray test.

Fan Schedules

The thermostat was set to provide comfort conditions at all times; no temperature setback or fan scheduling was implemented.

Fan Operation

The fans were set to cycle on a call for heating or cooling

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-1	1,870	2,000	93.5%	-4.4%
RTU-2	1,650	3,000	55.0%	-18.8%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC-1	732	730	0%
RTU-2	1,513	1,095	-38%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency Impact
AC-1	0.0	0.0
RTU-2	-1.3%	-2.5%

Maintenance Condition

Units were observed to be in average condition

Site 270 Kragen Auto Parts

Kragen Auto Parts Store #1360 at 1234 McHenry in Modesto is a single story 7000 square foot building. The space is used for retail sales. Heating and cooling for the building is provided by five Trane air conditioning units.

Testing Configuration

Diagnostic testing was performed on three units at this site: AC-1, AC-2 and AC-3. Each unit is a 3 ton Trane "Precedent" standard efficiency packaged rooftop air conditioner, model number YSC036A3RLA01D0012A.

Economizer Operation

Each unit contained a factory-installed economizer. The economizers passed the mechanical test. Economizer operation is controlled by the building automation system, so it was not possible to test the control function during inspection. Functioning economizers should reduce cooling costs by about 15% in this climate. The outdoor air dampers were observed to be fully closed. These dampers should be opened to admit fresh air to the building to improve indoor air quality.

Fan Schedules

The fan operating schedule is appropriate for the building occupancy.

Fan Operation

The fans are set up to cycle on a call for heating or cooling, and do not provide continuous air circulation to the building during occupied hours. This controls strategy, coupled with a lack of outside air at the rooftop unit can adversely affect indoor air quality.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM (@ 400 CFM/ton)	% of Normal
AC-1	1445	1200	120.4%
AC-2	1360	1200	113.3%
AC-3	1350	1200	112.5%

According to the test results, the units have sufficient air flow. Air flow rates exceeding 400 CFM/ton result in a slight increase in unit efficiency.

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC-1	273	438	38%
AC-2	346	438	21%
AC-3	435	438	1%

The units use less fan power than industry standards, indicating efficient fans and minimal pressure drop through the unit and the duct system.

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
AC-1	-7.8%	-7.3%
AC-2	Charge OK	No Impact
AC-3	-3.1%	-3.6%

Units AC-1 and AC-3 were slightly undercharged. The charge in these units was corrected as a part of the test procedure.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 273 - Playground Design

Playground Design at 1210 Keystone Way in Vista is a single story 29,595 square foot building. Heating and cooling for the building is provided by Trane packaged rooftop units

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
A/C South	Trane	WCCO48F400BF	4
N1	Trane	WC0048F400BF	4

Economizer Operation

The units tested at this site were not equipped with economizers.

Fan Schedules

The fans were not scheduled at this site, and run whenever there is a call for heating or cooling. The thermostats were programmed to provide comfort conditions at all times without a setback schedule.

Fan Operation

The fans in both units cycled on and off with a call for heating or cooling.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
A/C South	1,330	1,600	83.1%	-7.7%
N1	1,390	1,600	86.9%	-6.7%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
A/C South	659	584	-13%
N1	1,150	584	-97%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency Impact
A/C South	Charge OK	No Impact
N1	Charge OK	No Impact

Maintenance Condition

The units were observed to be in good condition

Other Issues

The electrical disconnect for unit A/C south was blocking the filter access panel.

Site 280 - Costco Wholesale

Costco Wholesale at 1345 N. Montebello Boulevard in Monterey Park is a single story 137,930 square foot building. Heating and cooling for the building is provided by twelve packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC2	Carrier	50NQ024-311	2
AC4	Carrier	50NQ030321	2.5

Economizer Operation

Both units were equipped with economizers, but the economizers were not operable.

Fan Schedules

The building is occupied from 4am to midnight 7 days per week. The fans are set to operate whenever there is a call for heating or cooling. A thermostat setback schedule has been implemented in both units

Fan Operation

Fans have been set up to cycle with a call for heating or cooling.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC2	872	800	109.0%	0.0%
AC4	1,021	1,000	102.1%	0.0%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	**Measured Watts**	**Normal watts**	**Fan Efficiency Impact**
AC2	353	292	-21%
AC4	396	365	-8%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
AC2	-7.46%	-7.0%
AC4	-7.29%	-6.8%

Maintenance Condition

The units were observed to be in average condition. The filters were dirty and needed to be changed.

Site 283 - Regenesis

Regenesis at 1011 Calle Sombre in San Clemente is a two-story 23,000 square foot building, consisting of conditioned office and unconditioned work and storage space. Heating and cooling for the building is provided by four Carrier packaged rooftop heat pumps.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1.1	Carrier	50TJQ005	4
AC-1.2	Carrier	50TJQ004	3
AC-1.6	Carrier	50TJQ006	5

Economizer Operation

None of the units tested at this site were equipped with economizers.

Fan Schedules

The fans are scheduled to be on during the occupied period, which is nominally 8 am to 5 pm. Fan schedules vary by unit, but generally start between 6:30am and 7am, and shut down between 5pm and 6:30pm.

Fan Operation

The fans are set up to run continuously during occupied hours and shut off during unoccupied hours.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-1.1	1,210	1,600	75.6%	-9.6%
AC-1.2	860	1,200	71.7%	-10.9%
AC-1.6	1,020	2,000	51.0%	-20.6%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC-1.1	457	600	22%
AC-1.2	352	450	20%
AC-1.6	464	750	36%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency Impact
AC-1.1	-10.6%	-10.1%
AC-1.2	-9.7%	-9.2%
AC-1.6	Charge OK	No impacts

Maintenance Condition

Units were observed to be in good condition.

Site 314 - St. Maximilian Kolbe Catholic Church

St. Maximilian Kolbe Catholic Church at 5801 Kanan Road in Thousand Oaks is a single story 64,260 square foot building. Heating and cooling for the building is provided by several large Carrier packaged rooftop air conditioners. One small system of 3.5 tons serves an electrical equipment room.

Testing Configuration

Diagnostic testing was performed on the following unit at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-7	Carrier	50SX-042-601-AA	3.5

Economizer Operation

The unit tested was not equipped with an economizer

Fan Schedules

Fan is scheduled on 24/7, consistent with use of space.

Fan Operation

Fan cycles with call for cooling, which is appropriate for an unoccupied electrical equipment room.

Unit Air Flow

The air flow rate for the unit tested was measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-7	790	1,400	56.4%	-18.0%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC-7	417	511	18%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
AC-7	Charge OK	No impact

Maintenance Condition

The unit was observed to be in good condition.

Site 317 - Soka University Maintenance Building

The Soka University Maintenance Building in Aliso Viejo is a single story 18,000 square foot building. Heating and cooling for the building is provided by a single 12.5 ton Trane packaged rooftop units serving 3000 square feet and several split system air conditioners. Approximately 9,000 square feet is unconditioned.

Testing Configuration

Diagnostic testing was performed on the following unit at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC1	Trane	WCH1508400EA	12.5

Economizer Operation

The economizer in the unit tested was not functional.

Fan Schedules

The space is occupied 7am to 5pm Monday – Friday. The fans are scheduled to operate from 8am to 8pm Monday-Friday.

Fan Operation

The fans are set up to cycle with a call for heating and cooling during the occupied hours.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency impact
AC1	3,632	5,000	72.6%	-10.6%

Supply Fan Power

The supply fan power for the unit tested was measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC1	1,667	1,825	9%

Refrigerant Charge

The results of the refrigerant charge test is summarized below:

Unit	Charge deviation	Cooling Efficiency impact
AC-1	Charge OK	No Impact

Maintenance Condition

The unit was observed to be in good condition.

Site 325 - Valencia Commerce Center Building B

The Valencia Commerce Center Building B at 28305 Livingston Ave. in Valencia is a single story 6,000 square foot building, consisting of conditioned office and unconditioned warehouse space. Heating and cooling for the building is provided by four Carrier packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following unit at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
RTU-1	Carrier	5DTJQ006-601GA	5

Economizer Operation

The unit tested was not equipped with an economizer.

Fan Schedules

All units in building are controlled by a Honeywell XBS EMS. The fans are scheduled to follow the building occupancy schedule, which is 7am - 10:30pm Monday-Friday.

Fan Operation

Fans are controlled by the Honeywell XBS EMS. The fans run continuously during occupied hours.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
RTU-1	1,480	2,000	74.0%	-10.1%

Supply Fan Power

The supply fan power for the unit tested was measured as follows:

Unit	Measured Watts	Normal Watts	Fan efficiency impact
RTU-1	770	730	-5%

Refrigerant Charge

The results of the refrigerant charge test is summarized below:

Unit	Charge deviation	Cooling efficiency impact
RTU-1	-5.4%	-5.3%

Maintenance Condition

The unit was observed to be in average condition.

Site 332 – Raymond Building

The Raymond Building at 1955 S. Burgundy Pl. in Ontario is a single story 27,588 square foot building, consisting of conditioned office and unconditioned warehouse space. Heating and cooling for the building is provided by four packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
E-2	Carrier	50JS-036-601	3
East 1	Carrier	50JS-036-601	3

Economizer Operation

None of the units tested at this site had economizers.

Fan Schedules

The fan schedule follows the building occupancy, which is 6am to 6pm, Monday-Friday.

Fan Operation

The fans are set up to run continuously during occupied hours.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
E-2	960	1,200	80.0%	-8.4%
East 1	950	1,200	79.2%	-8.6%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal watts	Fan efficiency impact
E-2	613	438	-40%
East 1	601	438	-37%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
E-2	-1.75%	-2.7%
East 1	Charge OK	No impact

Maintenance Condition

The units were observed to be in average condition.

Site 339 - In Motion Fitness

In Motion Fitness at 1293 E. 1st Avenue in Chico is a single story 11,000 square foot building. Heating and cooling for the building is provided by eleven rooftop air conditioning units.

Testing Configuration

Diagnostic testing was performed on the following unit at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-11	Carrier	48HJD008	7.5

Economizer Operation

The economizers passed the mechanical test of actuator and linkage. It also passed the cold air spray test.

Thermostat and Fan Schedules

The building is occupied 24 hours per day, 7 days per week. The systems are set up to run continuously 24/7 to maintain occupied period setpoints. A thermostat at west wing entrance was investigated. The thermostats were set at 69 °F for cooling and 66 °F for heating. The indicated and measured space temperature was 71 °F and 70 °F. The setpoint can be changed to 74 °F for cooling as suggested, which could create substantial savings.

Fan Operation

The fans are set up to run continuously during the occupied period.

Unit Air Flow

The air flow rates for the unit tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-11	2,399	3,000	80.0%	-8.4%

The measured air flow of the units was less than the standard air flow rate used by manufacturers to rate the efficiency of their systems. Increasing the air flow to the standard value will improve the efficiency of the air conditioners tested by about 8%.

Supply Fan Power

The supply fan power for the unit tested was measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC-11	1,490	1,095	-36%

According to the test results, the unit fan power in watts per cfm of air flow is above normal, causing excessive energy consumption during fan operation. This problem can be caused by excessive distribution system pressure drop.

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
AC-11	-19%	-23%

Refrigerant charges on both circuits of AC-11 unit were under charged. It impacts the efficiency and the capacity of the unit. The charge in this unit was corrected as a part of the test procedure.

Maintenance Condition

The units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 340 - Young Nak Presbyterian Church

The Young Nak Presbyterian Church at 18101 Lassen Street in Northridge is a single story 11,500 square foot building. Heating and cooling for the building is provided by Carrier packaged rooftop air conditioners.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
RTU-3-1	Carrier	50JTJQ012-501GA	10
AC-1	Carrier	50TJQ005-501GA	4

Economizer Operation

Two rooftops, AC-1 and RTU-3-1, were investigated. AC-1 does not have an economizer. The economizer of RTU-3-1 was stuck at wide open.

Thermostat and Fan Schedules

Building occupancy for office area is Monday to Friday from 8:00 to 16:00. The sanctuary is occupied on Sunday from 8:00 to 14:00. Five thermostats were investigated. The cooling was set between 70 to 72 °F and the heating was set between 60 to 70 °F. However, the occupants can override the thermostat. One of the thermostat at the sanctuary area was set at 64 °F for cooling. The measured space temperature was at 67 °F. The occupants might have set the space temperature very low to cool the space down very rapidly, however, the savings could be substantial if the thermostats are set appropriately. The suggested thermostat setting is 74-76 °F for cooling and 70°F for heating.

Fan Operation

The systems are set up to cycle to maintain occupied period setpoints, and schedule the systems off during unoccupied periods.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
RTU-3-1	3,760	4,000	94.0%	-4.1%
AC-1	1,300	1,600	81.3%	-8.1%

Both unit has low airflow. Low air flow can cause reduced cooling capacity, reduced unit efficiency, and coil icing during humid weather. The correct airflow would improve the efficiency of the unit by 4% to 8%.

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
RTU-3-1	1,920	1,460	-32%
AC-1	516	584	12%

According to the test results, the unit fan power for RTU-13 is above normal, causing excessive energy consumption during fan operation. This problem can be caused by excessive distribution system pressure drop.

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
RTU-3-1	-5.9%	-5.6%
AC-1	-10.64%	-10.1%

Refrigerant charges on both rooftop units were under charged. It impacts the efficiency and the capacity of the unit. The charges in these units were corrected as a part of the test procedure.

Maintenance Condition

All of the units appeared to be in good condition. However, the filters in the units were very dirty. It appears that the units are not regularly serviced and maintained. The regular maintenance and service would improve the performance for the units and a healthy building.

Filter condition at Young Nak Church

Site 343 – Target

Target at 1871 N. Main Street in Walnut Creek is a single story 139,000 square foot building. Heating and cooling for the building is provided by AAON packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
RTU-1	Aaon	RK063E0222	6
RTU-5	Aaon	RR08-3-PO-212	8

Economizer Operation

The economizers passed the mechanical test of actuator and linkage. It also passed the cold air spray test.

Fan Schedules

Building occupancy is from 8 am to 10 pm everyday. Thermostats were set at 72/82 °F for cooling during occupied and unoccupied period, and 70/60 °F for heating during occupied and unoccupied period. The systems are set up to maintain occupied period setpoints for occupied periods; and schedule the systems off during unoccupied periods.

Fan Operation

Approximately 50% of the units cycle fan with load, the other half of the units have fans that run at all times during occupied hours.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
RTU-1	2,403	2,400	100.1%	0.0%
RTU-5	3,991	3,200	124.7%	0.0%

Both systems have adequate airflow. No adjustment was needed.

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan efficiency Impact
RTU-1	1,640	876	-87%
RTU-5	1,280	1,168	-10%

According to the test results, the unit fan power of RTU-1 is above normal, causing excessive energy consumption during fan operation. This problem can be caused by excessive distribution system pressure drop.

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
RTU-1	Charge OK	No Impact
RTU-5	Charge OK	No Impact

Both RTU-1 and RTU-2 were adequately charged. All rooftops at this site were scheduled to be checked on refrigerant charge twice a year (fall/spring).

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 347 - Greybar Electric

Greybar Electric at 383 Cheryl Lane in City of Industry is a two-story 278,380 square foot building consisting of conditioned offices and unconditioned warehouse space. Heating and cooling for the offices is provided by Trane packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following unit at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
RTU-4	Trane	YFD075C4LCBE	6.25

Economizer Operation

The tested unit has no economizer.

Thermostat and Fan Schedules

Building occupancy is from 6 am to 5 pm Monday to Friday. Thermostats were set at 72 to 75 °F on cooling. However, the measured room temperature was between 71 to 73 °F. From three thermal comfort surveys, all occupants indicated that the space was too cold. Therefore, the thermostat could be set at a higher temperature. It would create better comfort and energy savings.

Fan Operation

The systems are set up to maintain occupied period setpoints for occupied periods; and schedule the systems off during unoccupied periods.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Efficiency Impact
RTU-4	2,590	2,500	103.6%	0.0%

According to the test results, the unit has sufficient air flow. Air flow rates exceeding 400 CFM/ton result in a slight increase in unit efficiency.

Refrigerant Charge

The results of the refrigerant charge test is summarized below:

Unit	Charge deviation	Efficiency impact
RTU-4	Charge OK	No impact

The unit was properly charge. No adjustment was made.

Maintenance Condition

The unit appeared to be in average condition. It appears that the unit is regularly serviced and maintained.

Site 365 - Budway Trucking

Budway Trucking at 13600 Napa Street in Fontana is a single story office and warehouse building. The area studied is a 3000 square foot open office addition. Heating and cooling for the building is provided by two 2 ton Carrier packaged rooftop units serving this space.

Budway Trucking, Front View

Roof top units serving new addition.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
Unit 1	Carrier	50HS-024031146	2
Unit 2	Carrier	50HS-0240311AB	2

Economizer Operation

None of the units studied were equipped with economizers.

Fan Schedules

The fans follow the space occupancy schedule, which is 6am – midnight, Monday-Friday.

Fan Operation

The fans are set up to operate continuously during the occupied period.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impacts
Unit 1	935	800	116.9%	0.0%
Unit 2	690	800	86.3%	-6.9%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan efficiency impact
Unit 1	359	292	-23%
Unit 2	329	292	-13%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
Unit 1	-20.90%	-24.4%
Unit 2	4.48%	0.1%

Maintenance Condition

The units were observed to be in average condition.

Site 376 - Home Depot

Home Depot at 9700 Lower Azusa Road in El Monte is a single story 130,000 square foot building. Heating and cooling for the building is provided by unit ventilators and three roof top air conditioning units

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-2	Carrier	48HJE004---631	3
RTU-3	Carrier	48HJD006---631	5

Economizer Operation

For the AC-2, the economizer was responding to the cold spray. However, the linkage is not tightly connected so when motor moves, the outside air damper does not move. For RTU-3, the economizer passed the actuator and cold spray tests.

Thermostat and Fan Schedules

Three thermostats were investigated. The first thermostat is at the bookkeeping and computer room. The heating and cooling setpoint was set at 45 °F / 58 °F. Although, the cooling setpoint was very low, the thermostat indicated the temperature in the room was at 71 °F. The unit could not reach the setpoint. It might caused by excessive load from computers that exceeds the unit capacity. The second thermostat is at the training room. The heating and cooling setpoint was set at 48 °F / 75 °F. The thermostat indicated the temperature in the room was at 70 °F. The third thermostat is at the break room. The heating and cooling setpoint was set at 67 °F / 72 °F. The thermostat indicated the temperature in the room was 72 °F.

Fan Operation

The fans were set to cycle on and off with a call for heating or cooling.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
Unit 2	789	1,200	65.8%	-13.4%
Unit 1	982	2,000	49.1%	-22.0%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
Unit 2	454	438	-4%
Unit 1	550	730	25%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Efficiency impact
Unit 2	-2.3%	-3.1%
Unit 1	Charge OK	No Impact

Maintenance Condition

Units were observed to be in average condition.

Site 388 - Genica

Genica at the Prescott Business Park in Oceanside is a single story 17,000 square foot office/warehouse building. Heating and cooling for the office portion of the building is provided by seven packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
Unit-1	ICP	PHF060L000A	5
Unit-2	ICP	PHF060L00A	5

Economizer Operation

Neither of the units studied at this site were equipped with economizers.

Fan Schedules

The building operates on a 7am – 5pm Monday-Friday schedule. The thermostats are residential style, so fan scheduling is not possible. The fans operate whenever there is a call for heating or cooling.

Fan Operation

The fans are set up to cycle on whenever there is a call for heating or cooling.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
Unit-1	1,550	2,000	77.5%	-9.1%
Unit-2	1,395	2,000	69.8%	-11.7%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan efficiency impact
Unit-1	820	730	-12%
Unit-2	630	730	14%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
Unit-1	19.89%	-1.7%

Maintenance Condition

The units were observed to be in average condition.

Site 402 - Home Depot Distribution Center

Home Depot Distribution Center at 8535 Oakwood Pl. in Rancho Cucamonga is a single story 220,000 square foot office/warehouse building. Heating and cooling for the conditioned office portion of the building is provided by two Rheem packaged rooftop units.

Building Entrance

Two Rheem packaged rooftop units conditioning the office.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
RTU-1	Rheem	RJKA-A048DM	4
RTU-2	Rheem	RJKA-A060DM	5

Economizer Operation

Neither of the units tested were equipped with economizers.

Fan Schedules

The office portion of the building is occupied from 6am to 3pm Monday-Friday. The thermostats are programmed to operate the fans 24 hours per day, 7 days per week.

Fan Operation

The fans are set up to cycle on a call for heating or cooling

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
RTU-1	1,935	1,600	120.9%	0.0%
RTU-2	1,705	2,000	85.3%	-7.1%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal watts	Fan efficiency impact
RTU-1	950	584	-63%
RTU-2	740	730	-1%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Efficiency impact
RTU-1	22.6%	-0.3%
RTU-2	34.7%	-6.5%

Maintenance Condition

The units were observed to be in average condition.

Site 407 - Albertson's

The Albertson's at 715 El Camino Real in Mountain View is a single story 60,000 square foot building. Heating and cooling for the building is provided by a combination of four packaged rooftop units and air handlers served from a refrigeration rack.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1	Trane	YCD036C4LGBE	3
AC-2	Trane	YCD036C4LGBE	3

Economizer Operation

Both units were equipped with economizers. Unit AC-1 had a non-functioning damper actuator.

Fan Schedules

The fans follow the building occupancy, which is 24 hours/day, 7 days per week. The unit is controlled by a central EMS, with setpoints and schedules determined by the Corporate office.

Fan Operation

The fans are set up to run continuously.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling efficiency impact
AC-1	1,222	1,200	101.8%	0.0%
AC-2	1,059	1,200	88.3%	-6.3%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan efficiency impact
AC-1	460	438	-5%
AC-2	320	438	27%

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling efficiency impact
AC-1	-5.7%	-5.5%
AC-2	0.%	0.%

Maintenance Condition

The units were observed to be in poor condition. Unit AC-1 had a broken economizer actuator and very dirty filters. Unit AC-2 had very dirty filters, resulting in a dirty evaporator coil. Unit 3, a 7.5 ton unit not studied had a broken fan belt.

Site 467 - Clover Springs Rec Center

The Clover Springs Rec Center and Swimming Pool at 210 Red Mountain Road in Cloverdale is a single story 8000 square foot building. Heating and cooling for the building is provided by four York air conditioning units, ranging from 4 tons to 10 tons.

Clover Springs Rec Center Rooftop Air Conditioners

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-1	York	D3CG120N16525D	10
AC-2	York	D3C6120N16525D	10
AC-3	York	D2C6072N07925A	6
AC-4	York	D7CG048N06025A	4

Economizer Operation

None of the units were equipped with economizers. The six and ten ton units, according to the California Title 24 Energy Standards, should be equipped with economizers.

Thermostat and Fan Schedules

Building occupancy is from 7 am to 8 pm Monday through Saturday, and 8 am to 3 pm Sundays. The systems are set up to continuously maintain occupied period setpoints with no temperature setback. The fan controls are set up to provide continuous ventilation air to the building during occupied hours.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-1	2667	4000	66.7%	-11%
AC-2	2903	4000	72.6%	-10%
AC-3	1044	2400	43.5%	> -20%
AC-4	1163	1600	72.7%	-10%

According to the test results, all units have low air flow. Low air flow can cause reduced cooling capacity, reduced unit efficiency, and coil icing during humid weather. The loss of efficiency ranges from 10% to 20+%.

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC-1	1,610	1,460	-10%
AC-2	1,830	1,460	-25%
AC-3	774	876	12%
AC-4	631	584	-8%

According to the test results, the unit fan power is above normal in three of the four units tested, causing excessive energy consumption during fan operation. This problem can be caused by excessive distribution system pressure drop.

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Cooling Efficiency impact
AC-1	Significantly under charged, no adjustment made	-20+%
AC-2	No charge in unit	Unit does not operate
AC-3	Significantly under charged, no adjustment made	-20+%
AC-4	OK	No impact

Units AC-1, AC-2, and AC-3 were significantly undercharged. AC-2 was essentially discharged, and would not operate. The charge in AC-4 is adequate.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained. The charge problems mentioned above must be addressed to restore the units to full capacity and efficiency.

Site 484 - Temple Baptist Church

Temple Baptist Church at 801 S. Lower Sacramento Road in Lodi is a two-story 24,000 square foot building. Heating and cooling for the building is provided by twelve Trane air conditioning units. Two units were investigated in detail.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
AC-10	Trane	YCD074C4CABE	6.25
AC-11	Trane	YCD121C4LAAA	10

Economizer Operation

Each unit contained a factory-installed economizer. The economizers passed the mechanical test under Trane Test Mode. Economizer operation is controlled by the building automation system, so it was not possible to test the control function during inspection.

Thermostat and Fan Schedules

Building occupancy is from 7 am to noon on Sundays. The units are controlled by a Trane Tracker EMS. The EMS is set up to maintain occupied period setpoints for occupied periods; and schedule the systems off during unoccupied periods.

Fan Operation

The EMS is set up to operate the fans continuously during the occupied period, and schedule the fans off during the unoccupied period.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Standard CFM @ 400 CFM/ton	% of Normal	Cooling Efficiency Impact
AC-10	2,030	2,500	81.2%	-8.1%
AC-11	3,390	4,000	84.8%	-7.3%

The measured air flow of the units was less than the standard air flow rate used by manufacturers to rate the efficiency of their systems. Increasing the air flow to the standard value will improve the efficiency of the air conditioners tested by about 7% - 8%.

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal Watts	Fan Efficiency Impact
AC-10	860	913	6%
AC-11	1,600	1,460	-10%

According to the test results, the unit fan power in unit AC-11 is above normal, causing excessive energy consumption during fan operation. This problem can be caused by excessive distribution system pressure drop.

Refrigerant Charge

The results of the refrigerant charge tests are summarized below:

Unit	Charge deviation	Efficiency impact
AC-10	Charge OK	No impact
AC-11	Charge OK	No impact

Both AC-10 and AC-11 were adequately charged.

Maintenance Condition

All of the units appeared to be in good condition. The filters in the units were clean, and it appears that the units are regularly serviced and maintained.

Site 525 - Laguna Hills Senior Center

The Laguna Hills Senior Center at 24671 Via Iglesia in Laguna Hills is a single story 8,000 square foot building. Heating and cooling for the building is provided by three Carrier packaged rooftop units.

Testing Configuration

Diagnostic testing was performed on the following units at this site:

Unit Number	Make	Model Number	Cooling Capacity (tons)
RTU-1	Carrier	48TJD007-521	6
RTU-2	Carrier	48TJD007-521	6

Economizer Operation

Neither unit tested at this site is equipped with an economizer.

Fan Schedules

The fans are scheduled to follow the building occupancy, which is 8am to 5pm, Monday-Friday.

Fan Operation

The fans run continuously during occupied hours and cycle with a call for heating or cooling during unoccupied periods. Although a setback schedule has been implemented, the cooling setback temperature (69F) is less than the setpoint temperature.

Unit Air Flow

The air flow rates for the units tested were measured as follows:

Unit	Measured CFM	Normal CFM @ 400 CFM/ton	% of Normal	Cooling efficiency impact
RTU-1	1,500	2,400	62.5%	-14.9%
RTU-2	1,170	2,400	48.8%	-22.0%

Supply Fan Power

The supply fan power for the units tested were measured as follows:

Unit	Measured Watts	Normal watts	Fan efficiency impact
RTU-1	900	876	-3%
RTU-2	560	876	36%

Refrigerant Charge

The results of the refrigerant charge test is summarized below:

Unit	Charge deviation	Cooling efficiency impact
RTU-1	-4.17%	-4.3%

Maintenance Condition

The units were observed to be in average condition.

Integrated Energy Systems Productivity & Building Science Program

A project of the State of California PIER Program

Element Four – Integrated Design of Small Commercial HVAC Systems
Impact Analysis
FINAL September 25, 2003

Deliverable 4.5.3

PIER
Public Interest Energy Research
CALIFORNIA ENERGY COMMISSION

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TABLE OF CONTENTS

1 INTRODUCTION

This document presents the results of the statewide impact analysis for Element 4 of the New Buildings Institute's *Integrated Energy Systems - Productivity & Building Science Program*, a Public Interest Energy Research (PIER) program. It is funded by California ratepayers through California's System Benefit Charges administered by the California Energy Commission under (PIER) contract No. 400-99-013, and managed by the New Buildings Institute. The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The focus of Element 4 is system integration issues affecting the installed efficiency of small packaged HVAC systems. For the purposes of this project, small systems are defined as single package rooftop air conditioners and heat pumps with cooling capacity of 10 tons or less. The impacts of correcting several problems researched during the conduct of this project at a statewide level are presented.

2 APPROACH

We utilized the same methodology in this study that was used to provide the California Energy Commission with estimates of the energy impacts of revisions to the title 24 energy efficiency standards in the AB970 process[1]. The process involved a series of parametric DOE2.1 E simulations of 990 non-residential buildings contained in the Statewide Nonresidential New Construction Baseline database (NRNC database)[2]. The impacts of avoiding the problems noted in the study are estimated by comparing the simulated energy consumption with and without the simulated problems. The impacts of fixing each problem in this study were evaluated individually, without accounting for interactive effects. A final run was done to look at the impacts of fixing all problems together, including their interactions.

The statewide impacts were projected using the California Statewide NRNC database, a collection of 990 buildings statistically selected to represent the majority of statewide NRNC activity. The buildings in the database represent the building types considered by the CEC in their non-residential sector forecasting models, with the exception of refrigerated warehouses, which generally do not contain HVAC Systems covered under this study. The majority of the data come from about 880 on-site surveys conducted during impact evaluation studies of the SCE and PG&E 1994 and 1996 NRNC energy efficiency programs. These data were supplemented with thirty audits from the impact evaluation of the 1995 SDG&E NRNC program and additional on-site surveys designed to supplement the existing data. Participants in utility energy-efficiency programs are included, but are weighted according to their general representation in the population. The population was defined using a listing of new construction projects obtained from F. W. Dodge. The Dodge database seeks to list all new construction projects that are valued over $200,000 and are expected to start within 60

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1 Architectural Energy Corporation, *Assembly Bill 970 Emergency Rulemaking – 2001 Update of California Nonresidential Building Energy Efficiency Standards, Volume IV- Impact Analysis. November 21, 2000.*

2 RLW Analytics et al, *California Non-residential New Construction Baseline* Study, California Board for Energy Efficiency, 1999

days. The data include renovations and expansions as well as entirely new buildings.[3] These data were filtered to exclude projects not covered under Title 24. The population-weighted square footage distribution of audited sites in the NRNC database is shown by building type in Figure 1. These data are compared to estimates of new construction activity in 2001 supplied by the CEC.

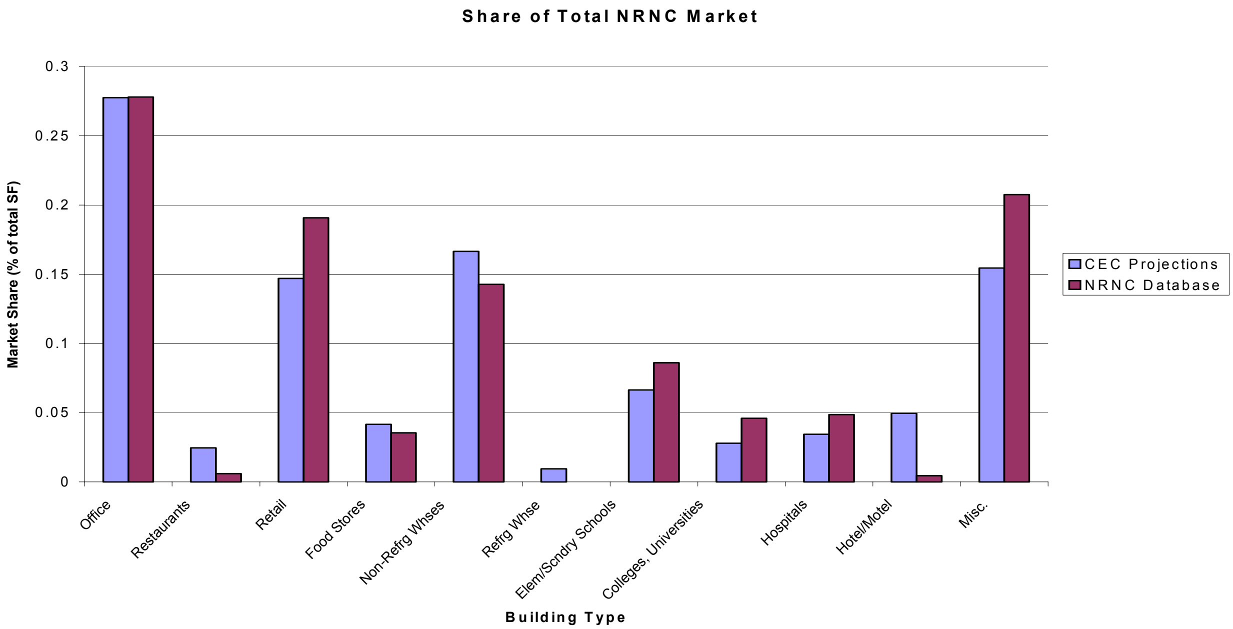


Figure 1 - Estimates of NRNC Construction Activity by Building Type

Note: the market share distribution in the NRNC database and the CEC projections are fairly close in most important market categories. Notable exceptions are the Restaurant and Hotel/Motel sectors, which generally do not comprise a large fraction of the total NRNC activity. Refrigerated warehouses are not considered, since they do not contain small HVAC Systems studied under this project. Buildings within the database were filtered to remove systems not covered under this project, such as built-up systems, water loop heat pumps, window air-conditioners, and so on. The resulting data base contained a total of 540 Buildings, each of which contained at least one small HVAC system.

During the audits, information on building physical characteristics such as types of lighting and plug load inventories, types and efficiency of HVAC equipment, insulation levels, and glazing properties were collected. Building occupants were interviewed to determine behavior characteristics such as occupancy schedules and equipment operation. The on-site data were used to develop DOE-2 building energy simulation models through an automated modeling process. Most building simulation models were calibrated to monthly billing data when the data were available.

The NRNC data represent the broad range of construction practices, climate zones and occupant behavior expected in a building population as diverse as the NRNC market. For example, the office segment contains a wide variety of buildings ranging from glass and steel skyscrapers to one-story

[3] The data are thought to cover over 95% of all projects that are competitively bid.

wood frame buildings. Each site in the sample has a statistically derived sample weight and precision, expressing the relative representation of each building in the NRNC population, thus allowing the results obtained from simulations of each individual building to be projected to the population with a quantifiable level of precision.

The energy consumption predicted for the population of buildings in the database was adjusted to reflect the Commission's estimate of NRNC activity for the year 2001. Table 1~~Table 1Table 1~~ summarizes the results.

Table 1. Summary of NRNC floor space and Commission New Construction Projections

Parameter	Value	Comments
Total floor space in NRNC database	233.2 million ft^2	Sum of weighted floor area in database
Estimated 2001 new construction activity	155.1 million ft^2	Excludes refrigerated warehouses
Adjustment factor	0.665	

3 NRNC DATABASE

On-site surveys conducted by energy engineers were used to develop the database. Building characteristics data were collected during the on-site survey and recorded on a form. The on-site survey data entry form was designed so that key modeling decisions on model zoning and equipment/space association were made by the surveyors in the field. The form was designed to follow the logical progression of an on-site survey process. The form started out with a series of interview questions. Conducting the interview first helped orient the surveyor to the building and allowed time for the surveyor to establish a rapport with the customer. Once the interview was completed, an inventory of building equipment was conducted. The survey started with the HVAC systems, and progressed from the roof and/or other mechanical spaces into the conditioned spaces. This progression allowed the surveyor to establish the linkages between the HVAC equipment and the spaces served by the equipment.

3.1 Interview Questions

The surveyor used the interview questions to identify building characteristics and operating parameters that were not observable during the course of the on-site survey. The interview questions covered the following topics:

Building functional areas. Functional areas were defined on the basis of operating schedules. Subsequent questions regarding occupancy, lighting, and equipment schedules, were repeated for each functional area.

Building Occupancy schedules. For each functional area in the building, a set of questions were asked to establish the building occupancy schedules. First, the surveyor assigned each day of the week to one of three daytypes: full occupancy, partial occupancy, and unoccupied. This was done to cover buildings that did not operate on a normal Monday through Friday workweek. Holidays and monthly variability in occupancy schedules were identified.

Daily schedules for occupants, interior lighting, and equipment/plug loads. A set of questions was used to establish hourly occupancy, interior lighting, and miscellaneous equipment and plug load schedules for each functional area in the building. During the on-site survey, the surveyor defined hourly schedules for each daytype. A value, which represents the fraction of the maximum occupancy and/or connected load was entered for each hour of the day.

Daily schedules of kitchen equipment. A set of questions were asked to establish hourly kitchen equipment schedules for each functional area in the building for each daytype. A value which represented the equipment-operating mode (off, idle, or low, medium or high volume production) was entered for each hour of the day.

Operation of the HVAC systems. A series of questions were asked to construct operating schedules for the HVAC systems serving each area. The surveyors entered fan operating schedules and heating and cooling setpoints. A series of questions were used to define the HVAC system controls. These questions were intended to be answered by someone familiar with the operation of the building mechanical systems. The questions covered operation of the outdoor air ventilation system, supply air temperature controls, and so on.

Refrigeration system. The operation of refrigeration systems utilizing remote condensers, which are common in groceries and restaurants, was covered in this section. Surveyors divided the systems into three temperature classes, (low, medium and high) depending on the compressor suction temperature. For each system temperature, the refrigerant, and predominant defrost mechanism was identified. Overall system controls strategies were also covered. Understanding the operation of the refrigeration is important due to the interactions of refrigerated cases with the HVAC system.

3.2 Building Characteristics

The next sections of the on-site survey covered observations on building equipment inventories and other physical characteristics. Observable information on HVAC systems, building shell, lighting, plug loads, and other building characteristics were entered, as described below:

Packaged HVAC systems. Equipment type, make, model number, and other nameplate data were collected on the packaged HVAC systems in the building.

Zones. Based on an understanding of the building layout and the HVAC equipment inventory, basic zoning decisions were made by the surveyors according to the following criteria:

- ***Unusual internal gain conditions***. Spaces with unusual internal gain conditions, such as computer rooms, kitchens, laboratories were defined as separate zones.
- ***Operating schedules***. Occupant behavior varies within spaces of nominally equivalent use. For example, retail establishments in a strip retail store may have different operating hours. Office tenants may also have different office hours.

- ***HVAC system type and zoning***. When the HVAC systems serving a particular space were different, the surveyors sub-divided the spaces according to HVAC system type. If the space was zoned by exposure, the space was surveyed as a single zone, and a “zone by exposure” option was selected on the survey form.

For each zone defined, the surveyor recorded the floor area and occupancy type. Enclosing surfaces were surveyed, in terms of surface area, construction type code, orientation, and observed insulation levels. Window areas were surveyed by orientation. The surveyor also identified and inventoried basic window properties, interior and exterior shading devices, lighting fixtures and controls, and miscellaneous equipment and plug loads.

Refrigeration systems. The surveyor inventoried the refrigeration equipment and associated the equipment with a particular zone in the building. Refrigerated cases and stand-alone refrigerators were identified by case type, size, product stored, and manufacturer. Remote compressor systems were inventoried by make, model number, and compressor system type. Each compressor or compressor rack was associated with a refrigerated case temperature loop and heat rejection equipment such as a remote condenser, cooling tower, and/or HVAC system air handler. Remote condensers were inventoried by make, model number, and type. Nameplate data on fan and pump hp were recorded. Observations on condenser fan speed controls were also recorded.

Cooking Equipment. The surveyor recorded the cooking equipment separately and associated with a particular zone in the building. Major equipment was inventoried by equipment type (broiler, fryer, oven, and so on), size, and fuel type. Kitchen ventilation hoods were inventoried by type and size. Nameplate data on exhaust flowrate and fan hp were recorded and each piece of kitchen equipment was associated with a particular ventilation hood.

3.3 Establishing Component Relationships

In order to create a DOE-2 model of the building from the various information sources contained in the on-site survey, relationships between the information contained in the various parts of the survey needed to be established. In the interview portion of the form, schedule and operations data were cataloged by building functional area. In the equipment inventory section, individual pieces of HVAC equipment were inventoried. In the zone section of the survey, building envelope data, lighting and plug load data were collected. The following forms provided the information needed by the software to associate the schedule, equipment, and zone information.

System/Zone Association Checklist. The system/zone association checklist provided a link between each building zone and the HVAC equipment serving that zone. Systems were defined in terms of a single or set of several units of packaged equipment. Each system was assigned to the appropriate thermal zones in accordance with the observed building design.

Interview “Area” / Audit “Zone” Association Checklist. Schedule and operations data gathered during the interview phase of the survey were linked to the appropriate building zone. These data were gathered according to the building functional areas defined previously. Each building functional area could contain multiple zones. This table facilitated the association of the functional areas to the zones, and thereby the assignment of the appropriate schedule to each zone.

3.4 Modeling Procedures

The on-site survey data were entered by the field engineering staff into a Microsoft Access application called SurveyIT. SurveyIT contains a series of relational data tables that store information for multiple buildings, and Visual Basic code that interfaces with the ModelIT automated modeling software. ModelIT is C++ code that reads SurveyIT data tables and automatically creates a DOE-2 input file for each building in the database. Once the basic building is described and an as-built DOE-2 model is created, the modeling software also creates additional DOE-2 input files for each of the building parametric runs.

The software is designed to create DOE-2 BDL (building description language) files that are recognized by DOE-2.2. The version of DOE-2.2 used for this project is Beta 2.2-41c. The data elements used, default assumptions, and engineering calculations are described for the Loads and Systems portions of the DOE-2.2 input file as follows.

3.4.1 Loads

Schedules were created for each zone in the model by associating the zones defined in the on-site survey with the appropriate functional area, and assigning the schedule defined for each functional area to the appropriate zone. Hourly schedules were created by the software on a zone-by-zone basis for:

- Occupancy
- Lighting
- Electric equipment
- Gas equipment (primarily kitchen equipment)
- Solar glare
- Window shading
- Infiltration

Occupancy, lighting, and equipment schedules. Each day of the week was assigned to a particular daytype, as reported by the surveyor. Hourly values for each day of the week were extracted from the on-site database according to the appropriate daytype. These values were modified on a monthly basis, according to the monthly building occupancy history.

Solar and shading schedules. The use of blinds by the occupants was simulated by the use of solar and shading schedules. The glass shading coefficient values were modified to account for the use of interior shading devices.

Infiltration schedule. The infiltration schedule was established from the fan system schedule. Infiltration was scheduled "off" during fan system operation, and was scheduled "on" when the fan system was off.

Shell materials. A single-layer, homogeneous material was described which contains the conductance and heat capacity properties of the composite wall used in the building. The thermal conductance and heat capacity of each wall and roof assembly was taken from the Title 24 documents, when available. If the Title 24 documents were not available, default values for the conductance and heat capacity were assigned from the wall and roof types specified in the on-site survey, and the observed R-values. If the R-values were not observed during the on-site survey and the Title 24 documents were not available, an "energy-neutral" approach was taken by assigning the same U-value and heat capacity for the as-built and Title 24 simulation runs.

Windows. Window thermal and optical properties from the building drawings or Title 24 documents (when available) were used to develop the DOE-2 inputs. If these documents were not available, default values for the glass conductance were assigned according to the glass type specified in the on-site survey. If the glass type was not observed during the on-site survey and the Title 24 documents were not available, an "energy-neutral" approach was taken by assigning the same U-value and shading coefficient for the as-built and Title 24 simulation runs.

Lighting kW. Installed lighting power was calculated from the lighting fixture inventory reported on the survey. A standard fixture wattage was assigned to each fixture type identified by the surveyors. Lighting fixtures were identified by lamp type, number of lamps per fixture, and ballast type as appropriate.

Equipment kW. Connected loads for equipment located in the conditioned space, including miscellaneous equipment and plug loads, kitchen equipment and refrigeration systems with integral condensers were calculated. Input data were based on the "nameplate" or total connected load. The nameplate data were adjusted using a "rated-load factor," which is the ratio of the average operating load to the nameplate load during the definition of the equipment schedules. This adjusted value represented the hourly running load of all equipment surveyed. Equipment diversity was also accounted for in the schedule definition.

For the miscellaneous equipment and plug loads, equipment counts and connected loads were taken from the on-site survey. When the connected loads were not observed, default values based on equipment type were used.

For the kitchen equipment, equipment counts and connected loads were taken from the on-site survey. Where the connected loads were not observed, default values based on equipment type and "trade size" were used. Unlike the miscellaneous plug load schedules, the kitchen equipment schedules were defined by operating regime. An hourly value corresponding to "off", "idle", or "low," "medium," or "high" production rates were assigned by the surveyor. The hourly schedule was developed from the reported hourly operating status and the ratio of the hourly average running load to the connected load for each of the operating regimes.

For the refrigeration equipment, refrigerator type, count, and size were taken from the on-site survey. Equipment observed to have an "integral" compressor/condenser that is, equipment that rejects heat to the conditioned space, were assigned a connected load per unit size.

Source input energy. Source input energy represented all non-electric equipment in the conditioned space. In the model, the source type was set to natural gas, and a total input energy was specified in terms of Btu/hr. Sources of internal heat gains to the space that were not electrically powered include kitchen equipment, dryers, and other miscellaneous process loads. The input rating of the equipment was entered by the surveyors. As with the electrical equipment, the ratio of the rated input energy to the actual hourly consumption was calculated by the rated load factor assigned by equipment type and operating regime.

Heat gains to space. The heat gains to space were calculated based on the actual running loads and an assessment of the proportion of the input energy that contributed to sensible and latent heat gains. This in turn depended on whether or not the equipment was located under a ventilation hood.

Spaces. Each space in the DOE-2 model corresponded to a zone defined in the on-site survey. In the instance where the "zoned by exposure" option was selected by the surveyor, additional DOE-2 zones were created. The space conditions parameters developed on a zone by zone basis were included in the description of each space. Enclosing surfaces, as defined by the on-site surveyors, were also defined.

3.4.2 Systems

This section describes the methodology used to develop DOE-2 input for the systems simulation.

Fan schedules. Each day of the week was assigned to a particular daytype, as reported by the surveyor. The fan system on and off times from the on-site survey was assigned to a schedule according to daytype.

Setback schedules. Similarly, thermostat setback schedules were created based on the responses to the on-site survey. Each day of the week was assigned to a particular daytype. The thermostat setpoints for heating and cooling, and the setback temperatures and times were defined according to the responses.

System type. The HVAC system type was defined from the system description from the on-site survey. The DOE-2 Packaged single zone (PSZ) system type was used to simulate the small HVAC systems studied in this project.

Packaged HVAC system efficiency. Manufacturers' data were gathered for the equipment surveyed based on the observed make and model number. A database of equipment efficiency and capacity data was developed from an electronic version of the ARI rating catalog. Additional data were obtained directly from manufacturers' catalogs, or the on-line catalog available on the ARI website (www.ari.org). Manufacturers' data on packaged system efficiency is a net efficiency, which considers both fan and compressor energy. DOE-2 requires a specification of packaged system efficiency that considers the compressor and fan power separately. Thus, the manufacturers' data were adjusted to prevent "double-accounting" of fan energy, according to the procedures described in the Title 24 Alternative Compliance Method (ACM) approval manual.

Refrigeration systems. Refrigeration display cases and/or walk-ins were grouped into three systems defined by their evaporator temperatures. Ice cream cases were assigned to the lowest temperature circuit, followed by frozen food cases, and all other cases. Case refrigeration loads per lineal foot were taken from manufacturers' catalog data for typical cases. Auxiliary energy requirement data for evaporator fans, anti-sweat heaters, and lighting were also compiled from manufacturers' catalog data. Model inputs were calculated based on the survey responses. For example, if the display lighting was surveyed with T-8 lamps, lighting energy requirements appropriate for T-8 lamps were used to derive the case auxiliary energy input to DOE-2.

Compressor EER data were obtained from manufacturers' catalogs as a function of the suction temperatures corresponding to each of the three systems defined above. These data were used to create default efficiencies for each compressor system. Custom part-load curves were used to simulate the performance of parallel-unequal rack systems.

4 FIELD TESTING

To conduct this research, teams of engineers visited 75 newly constructed commercial buildings throughout California. A total of 215 rooftop units were surveyed. Units were subjected to a physical inspection, a series of one-time tests, and short-term monitoring of unit performance. Up to four units per building were selected for study. Tests were performed at the individual HVAC units to better understand their performance, as described below.

4.1 One-time testing.

A series of one-time tests were used to quantify system and equipment performance. Examples of one-time tests included instantaneous measurements of unit supply fan power, refrigeration charge measurements, and unit air flow measurements. Functional performance tests of HVAC unit operation were conducted to identify gross deficiencies in unit performance, as described below:

4.1.1 Fan flow and Power

The unit was cycled through each mode of operation (standby, fan-only, cooling stage one, and cooling stage two, if applicable) and the true electric power and current of the unit were measured during each mode using a portable wattmeter. Airflow rate was measured using a flow grid, which is an averaging flow meter designed to be installed in place of the filters. A digital micromanometer was used to measure the pressure drop across the plate. The results were displayed directly in cfm. The manometer was also used to measure supply static pressure, return static pressure, and total unit external static pressure.

4.1.2 Economizer

If the unit had an airside economizer, the minimum outdoor air position potentiometer was adjusted to test the operation of damper motors and linkages. The economizer outdoor air temperature sensor was cooled down using a "cool" spray, simulating cool outdoor air conditions and the response of the economizer was observed.

4.1.3 Refrigerant charge

Service gauges and temperature sensors were used to verify the state of charge of the rooftop unit using the CheckMe![1] Procedure. The high side and low side pressures were measured, along with the suction line temperature, the condensed liquid temperature, outdoor drybulb temperature entering the condenser, and drybulb and wet bulb temperature entering the evaporator coil. Refrigerant was added or removed from the system until the suction line superheat on units with fixed metering devices, or the condenser line subcooling on units with thermostatic expansion valves (TXV), was within the target specified by the CheckMe! software.

4.2 Short-term monitoring.

HVAC system performance over a variety of operating conditions was observed through short-term monitoring of a sample of HVAC units and controls. Portable, battery-powered dataloggers were used to collect short-term data on HVAC unit performance. The purpose of the short-term monitoring was to spot failure modes that are not obvious from inspection or one-time test, or that only manifest themselves during the dynamic operation of the equipment. Data loggers were left in place on each building for about two weeks.

The dataloggers were configured to measure unit current, supply air temperature, return air temperature, and mixed air temperature. The data were stored on a five minute basis. The dataloggers used thermistor sensors with a 0.5°F accuracy over the full range. The current sensors were equipped with signal conditioning equipment to provide true RMS current readings. True RMS current measurements were coupled with the spot kW and current measurements to estimate time series kW data for the unit. In addition to the datalogger installed at each unit, the local rooftop temperature and humidity was monitored at each site.

5 PROBLEMS STUDIED

This section in summarizes the problems observed in the study, and the approach taken to simulate the impacts of eliminating those problems. Problems identified include broken economizers, improper refrigerant charge, fans running during unoccupied periods, fan that cycle on and off with a call for heating and cooling rather than providing continuous ventilation air, low air flow, inadequate ventilation air, and simultaneous heating and cooling.

Thermostat setpoints. The system thermostats were observed to provide cooling and heating at occupied period setpoints during unoccupied periods. Implementing a thermostat setback during unoccupied periods saves energy without sacrificing comfort.

Fan controls. Although the primary function of the thermostat is to control the heating and cooling output of the unit, most thermostats also control the operation of the supply fan. System fans were found to be cycling on and off with a call for heating or cooling in 38% of the units tested. Title 24 Energy Standards require that all buildings not naturally ventilated with operable windows or other openings be mechanically ventilated. Mechanical ventilation is required to occur at least 55 minutes out of every hour that the building is occupied. Building outdoor ventilation air is typically supplied during fan operation, with the minimum quantity of outdoor air determined by the outdoor air damper minimum position. The supply of continuous fresh air during occupied hours relies on continuous operation of the HVAC unit supply fan. The Standards further require operation of the ventilation system at least one hour before normal building occupancy in order to purge potential build up of pollutants and outgassing from furniture, carpets, paint, etc.

Fan schedule. Fans were also observed to run continuously during unoccupied periods in 38% of the systems observed. While this practice improves the ventilation of the space, it represents an opportunity to save energy through thermostat setback and fan cycling during unoccupied periods.

Economizers. Economizers show a high rate of failure (63%) in the study. Of the 215 units tested, 123 units were equipped with economizers. Of these, 30 units (24%) would not move at all, 36 units (29%) did not respond when subject to simulated economizer operating conditions. Short term monitoring revealed that an additional 13 (10%) did not respond correctly over a range of operating conditions.

Distribution Systems. The efficiency of the HVAC system is a function of both the unit efficiency and distribution system efficiency. Distribution system efficiency is a function of duct design and installation practices, as well as architectural design decisions affecting environmental conditions imposed the duct system. Architectural design issues affecting distribution system efficiency include insulation placement (roof or ceiling), roof surface and color selection, and location of attic vents. We did not make any quantitative measurements of duct leakage in this study; however, the location, surface area and insulation levels of the duct systems were surveyed as part of the onsite survey process.

Supply Fan Power. HVAC unit efficiency is calculated from ARI standard test and rating procedures, which use a standard assumption for supply fan power to determine overall unit efficiency. The actual fan power is generally greater than the standard assumption, reducing the installed efficiency of the unit. Fan power in small HVAC systems is not regulated by Title 24, and can be a significant energy cost, especially in systems utilizing continuous ventilation through the HVAC system. The measured fan power at the in-situ flow rate was 0.18 kW/ton, which is about 20% higher than the nominal fan power assumed in the Title 24 energy standards (365 W/cfm or about .15 kW/ton).

Unit Air Flow. Units were tested for in-situ airflow rate. Overall, of the 79 units tested for airflow, 28 (39%) had airflow less than 300 cfm /ton. The average airflow rate was 325 cfm/ton. ARI standards are based on airflow rates of 400 cfm/ton. Low air flow can result in reduced system efficiency and coil icing. High air flow can also result in excessive fan energy and insufficient moisture removal.

Refrigerant Charge. Refrigerant charge was field tested by measuring unit operating conditions and refrigerant temperature and pressure. Of the 74 refrigerant tests conducted, 33 (46%) were found to be improperly charged. The average energy impact of refrigerant charge problems was about 5% of the annual cooling energy.

6 IMPACT ESTIMATION APPROACH.

The general approach taken to estimate the impacts of avoiding problems identified in the study leverage is information gathered during the field study with NRNC population characteristics contained within the NRNC database. The impacts of avoiding problems throughout all new construction activity can be estimated by simulating each building in the database with and without a particular problem. The extent and frequency of the problems were identified during the field study. The net impact is calculated from the impacts assuming all buildings have the problem times the frequency of problem occurrence as identified in the field study.

The baseline for the analysis assumes that each building in the database contains each of the problems observed. The impacts of avoiding the problems are calculated by comparing the differences in the energy consumption between the baseline run and each of the parametric runs. The baseline characteristics simulated in each building are summarized below:

Table 1. Baseline RTU System Assumptions

Building characteristic	Baseline assumption
THERMOSTAT SETPOINT AND FAN SCHEDULE	As surveyed in NRNC database
Fan mode	Intermittent fan mode all hours in 38% of the buildings
Economizer	Economizers inactive in 64% of the systems
Distribution system	15% of systems have ducts located in an unconditioned plenum with an average leakage rate of 36%
Fan power	Specific fan power set at 0.478 W/cfm (study average)
Air flow rate	Air flow rate set at 325 cfm/ton (study average)

Parametric 1. Thermostats. The process used to simulate the savings for this parametric was to replace the baseline thermostat heating and cooling setpoint and fan schedule with a schedule that follows the surveyed occupancy schedule. The heating setpoints is setback to 55°F and the cooling setpoints is set back to 85°F during unoccupied periods. The fan schedule is set to operate with a one hour purge cycle prior to occupancy.

Parametric 2. Fan mode. The procedure used to simulate savings for this parametric was to simulate constant fan operation during occupied hours, and simulate intermittent fan operation during unoccupied hours in all buildings in the database.

Parametric 3. Economizer. Economizers were disabled in the as built run randomly throughout the database to reflect the failure rate observed during the field testing. This parametric restored all economizers to a functioning state.

Parametric 4. Ducts. Buildings likely to have ductwork in an unconditioned space were chosen from the NRNC database to represent the type and size of buildings observed in the NBI PIER study and the Statewide BEA NRNC study.[4] Overall, 15% of the small packaged systems observed in these studies have ductwork in unconditioned space. The breakdown of building types observed to have ductwork in unconditioned space is as follows:

[4] Pacific Gas and Electric Company, "Nonresidential Duct Sealing and Insulation," Codes and Standards Enhancement Initiative Final Report, May 2003.

Table 2 – Building Types with Ductwork in Unconditioned Space

Building type	Percent of Buildings with Ducts Outside the Conditioned Space
Church	0.69%
Grocery	0.84%
Gym	0.07%
Light Manufacturing	6.76%
Office	5.98%
Restaurant	0.12%
School	0.61%
Single-story large retail	6.66%
Unconditioned warehouse	78.27%

Note: most of the buildings having ductwork in unconditioned space were warehouses containing conditioned office space, where the ductwork was run from the roof through the unconditioned warehouse to the conditioned office. Buildings meeting this description were randomly selected from the NRNC database such that the total building area affected by the duct efficiency calculations was 15% of the total, and the distribution of the building types matched the distribution above. All sites selected were simulated with an unconditioned plenum containing the supply and return duct systems. Leaky ducts with standard insulation levels and sealed ducts with improved insulation levels were simulated. Leaky systems were simulated with 36% total leakage evenly split between supply and return systems. Sealed systems were simulated with 8% total leakage evenly split between supply and return systems. Duct insulation levels were set at code values (R-4.2) and at improved insulation levels (R-8).

Parametric 5. Fan power. The specific fan power was reduced from 0.478 W/CFM (study-wide average) to 0.365 W/CFM in all buildings.

Parametric 6. Air Flow. Air flow rates were increased from 325 cfm/ton (study average) to 400 CFM/ton. The unit efficiency was adjusted to account for the increased flow rate as shown in the figure below:

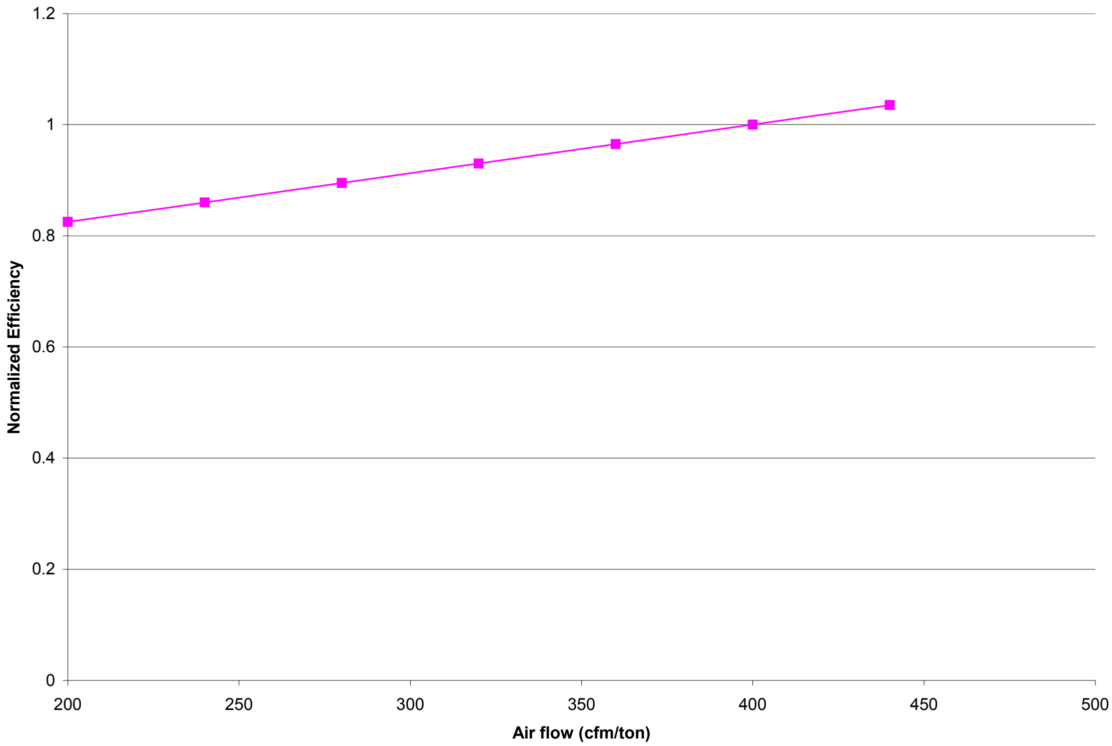


Figure 3 Unit Efficiency as a Function of Air Flow Rate

The HVAC unit cooling and heating efficiency was increased by 6.6% due to the increased flow rate. Fan energy was also increased in proportion to the increased air flow rate.

Parametric 7. Refrigerant Charge. The impact of correcting the refrigerant charge was simulated by applying a multiplier to the unit efficiency to count for the impact of correcting the refrigerant charge on unit efficiency. The impact of unit efficiency on charge is shown in Figure 4.

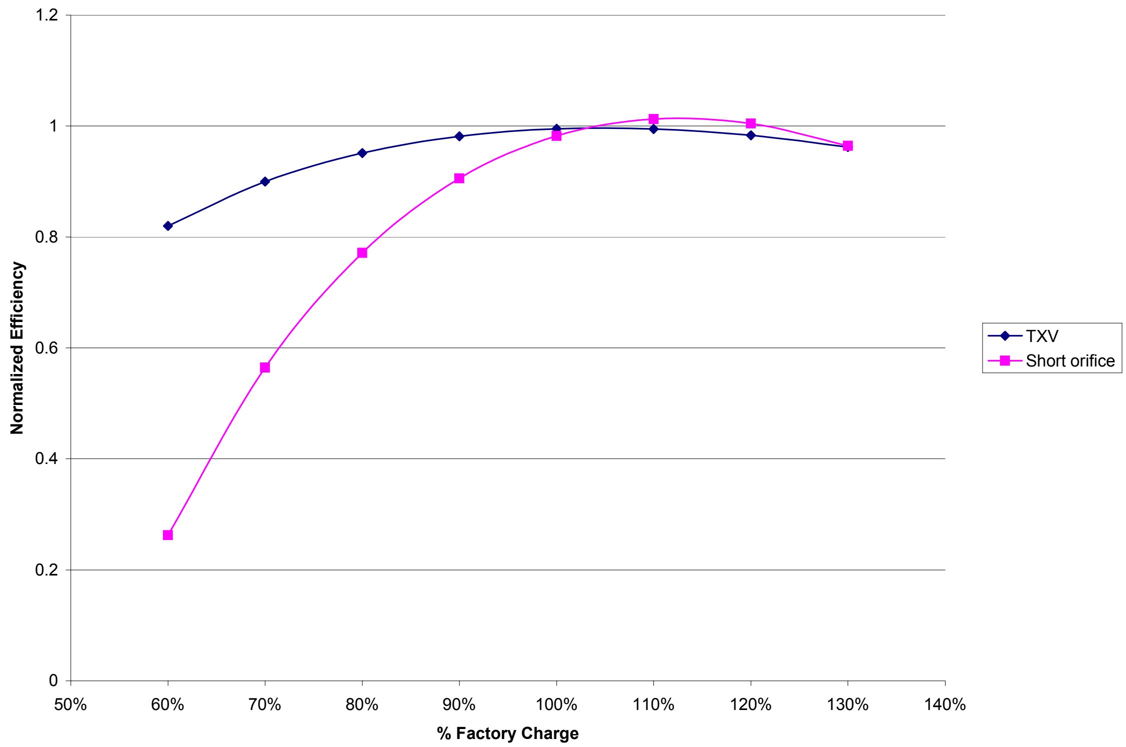


Figure 4. Unit Efficiency as a Function of Refrigerant Charge Deviation.

The unit cooling efficiency (and heating efficiency for heat pumps) was increased by 5%, based on the refrigerant charge distribution observed in the study.

7 RESULTS

The impacts were estimated on a whole-building and end-use basis for electricity and gas.

For each of the runs listed above, first year estimates of consumption and demand impacts were prepared. Coincident peak demand was reported at a specific hour of the year corresponding to the statewide system peak hour. Since the simulations were run using the CEC CTZ long-term average weather datasets, the coincident hour was estimated for each climate zone by identifying the hour most likely to correspond to the statewide peak. The coincident peaks by climate zone are evaluated as the average of the values for hours 17:00 and 18:00 on the following days:

Table 3 – Day of Year for Coincident Peak Analysis

CTZ	Month	Day (1995 Calendar)
1	7	21
2	7	24
3	7	18
4	7	18
5	9	5
6	9	8
7	7	31
8	7	20
9	8	8
10	8	14
11	8	3
12	7	24
13	8	15
14	8	7
15	7	21
16	8	7

The coincident demand value is reported by end-use, since the estimate is calculated at a particular hour of the year for all end-uses.

The first year results are summarized in Table 4. The end-uses are defined as follows:

- Whole building: Impact on electricity consumption and demand for all affected end-uses.
- Heating: Impact on electricity consumption and demand for the heating end-use. This is primarily derived from efficiency improvements applied to heat pumps.
- Cooling: Impact on electricity consumption and demand for the cooling end-use. This includes compressor and condenser fan energy consumption from packaged air conditioning systems, but excludes building fans.
- Fan: Impact on electricity consumption and demand for building circulation fans.

Note: When fan energy and air flow are corrected the energy use increases (creating a savings "penalty" to accomplish effective ventilation requirements). The subsequent energy savings of the other measures with these corrected items is greater then they are singularly resulting in an interactive total savings that exceeds the sum of the measures.

Table 4. First Year Electricity and Gas Consumption Impacts

Run	Measure	MWh Whole Blg.	MWh Heat	MWh Cool	MWh Fan	Gas Heat therm
1	Thermostats	21,086	763	6,052	14,149	1,230,940
2	Fan mode	-14,203	-1,042	6,154	-19,252	-375,865
3	Economizers	22,389	0	22,299	91	0
4	Duct losses	2,022	92	1,743	195	11,319
5	Fan Power	22,547	0	0	22,517	-52
6	Air flow	-8,796	336	12,003	-21,041	0
7	Refrigerant charge	9,349	255	9,094	0	0
8	All measures	69,421	557	62,476	6,296	971,068
	Total Consumption	831,381	5,091	181,881	101,970	3,214,944
	Savings %	8.4%	10.9%	34.3%	6.2%	30.2%

Note: Whole building savings are not equal to the sum of the end-use savings. See explanation above.

Table 5. First Year Electricity Demand Impacts

Run	Measure	Coin kW WB	Coin kW Heat	Coin kW Cool	Coin kW Fan
1	Thermostats	6,412	0	4,927	1,522
2	Fan mode	-2,949	0	-1,422	-1,517
3	Economizers	156	0	159	1
4	Duct losses	372	0	341	30
5	Fan Power	3,545	0	1	3,542
6	Air flow	1,672	0	5,099	-3,358
7	Refrigerant charge	5,985	0	5,985	0
8	All measures	14,855	4	13,495	1,434
	Total Demand	244,698	23,700	118,418	19,542
	Savings %	6.1%	0.0%	12.7%	1.1%

Note: Note: Whole building savings are not equal to the sum of the end-use savings. See explanation above.

In summary, the energy and market impact conclusions are:

- Average building electricity savings are 8.4% and natural gas savings are 30.2% resulting in a combined average energy cost saving of $0.26 /square foot.
    - The average energy increase from refrigerant charge problems was about 5% of the annual cooling energy.
    - The annual energy increase from low airflow is about 9% of the annual cooling energy.
    - The average measured fan power was about 20% higher than the assumptions used in the Title 24 Energy Standards, causing a commensurate increase in the annual fan energy.
- Average annual building electricity demand savings are 6.1%
- The annual new commercial construction in California is 157 million square per year. Of this, it is estimated that 39.7 million square feet (~25%) will be served by packaged units between 1 and 10

tons in size. With a first year market penetration of 10%, annual energy savings are estimated to be 6,942 MWh. With an increase in market penetration of 1% per year, the ten year cumulative electric energy savings is 496,360 MWhs equal to energy cost savings over this period of $68 million.

- Statewide demand savings are estimated at 1,486 kW per year (1.5 MW) based on a first year market penetration of 10%. With an increase in market penetration of 1% per year, the demand savings in year ten is 21.5 MW.
- The natural gas savings are estimated to be 97,107 therms first year savings resulting in a cumulative 10 year savings of 6,943,000 therms and a resulting cost savings of $5.8 million.
- The total net energy benefits over ten years to citizens of California would be $73.8 million.

APPENDIX A – COMPUTER MODELING ASSUMPTIONS

This appendix describes the basic approach used by the SurveyIT/ModelIT software to generate DOE-2 models from building survey data in the NRNC database.

SURVEYIT/MODELIT DESCRIPTION

SurveyIT is a Microsoft Access application that contains a user interface for entering building description information. SurveyIT contains a series of relational data tables that store information for multiple buildings, and Visual Basic code that interfaces with the ModelIT software. ModelIT is C++ code that reads SurveyIT data tables and automatically creates a DOE-2 input file for each building in the database. Building description data sources include the on-site survey, building design documents, Title 24 documents, and manufacturers' catalog data. Once the basic building is described and an as-built DOE-2 model is created, the modeling software also creates additional DOE-2 input files for each of the building parametric runs.

The software is designed to create DOE-2 BDL (building description language) files that are recognized by DOE-2.2. The version of DOE-2.2 used for this project is Beta 2.2-41c. The data elements used, default assumptions, and engineering calculations are described for the Loads and Systems portions of the DOE-2.2 input file in the following sections.

LOADS

Preliminary data required by the LOADS program are assigned as summarized below:

DOE-2 Input	Value	Comments
RUN-PERIOD	JAN 1 1995 THRU DEC 31 1995	
ALTITUDE	Altitude assigned to each building according to location	
GROSS-AREA	Sum of all surveyed area	
DAYLIGHT-SAVINGS	YES	
HOLIDAYS	New Years = Jan 2 MLK day = Jan 10 Presidents day = Feb 20 Memorial day = May 29 July 4th = July 4 Labor day = Sep 4 Columbus day = Oct 23 Thanksgiving = Nov 23 Christmas = Dec 25	Holidays observed at site taken from on-site survey.

SCHEDULES

Schedules are created for each zone in the model by associating the zones defined in the on-site survey with the appropriate functional area, and assigning the schedule defined for each functional area to the appropriate zone. Hourly schedules are created by the software on a zone-by-zone basis for:

- Occupancy
- Lighting
- Electric equipment
- Gas equipment (primarily kitchen equipment)
- Solar glare
- Window shading
- Infiltration

Occupancy, lighting, and equipment schedules. Each day of the week is assigned to a particular daytype, as reported by the surveyor. Hourly values for each day of the week are extracted from the on-site database according to the appropriate daytype. These values are modified on a monthly basis, according to the monthly building occupancy history. The basic format of the schedules is shown below:

THRU JAN 31

(MON) (1)(hour 1 schedule value for Monday daytype * monthly occupancy adjustment)

(2)(hour 2 schedule value for Monday daytype * monthly occupancy adjustment)

(3)(__)..

(24)(__)

(TUE) (1)(hour 1 schedule value for Tuesday daytype * monthly occupancy adjustment)

(2)(hour 2 schedule value for Tuesday daytype * monthly occupancy adjustment)

(3)(__)..

(24)(__)

THRU FEB 28…

ETC.

Solar and shading schedules. The use of blinds by the occupants is simulated by the use of solar and shading schedules. The glass shading coefficient values are modified to account for the use of interior shading devices as shown below:

Shading type	Adjustment	Comments
Blinds	0.78	89 ASHRAE Handbook of Fundamentals, pg. 27.30 Table 25 for 0.6 SC, avg. multiplier
Light shades	0.72	89 ASHRAE Handbook of Fundamentals, pg. 27.31 Table 29 for 0.6 SC, “F”
Dark shades	0.82	89 ASHRAE Handbook of Fundamentals pg. 27.31 Table 29 for 0.6 SC, “D”

The adjustment value schedule are determined from the interview response, as shown below:

Interview response	Schedule
Always open	No adjustment
Always closed	Adjustment factors applied to all hours
Operated by occupants to control comfort	Deployed when solar radiation exceeds seasonal threshold value
Open when space is occupied	Follows zone occupancy schedule

When the shades are operated by occupants to control comfort, the threshold values of solar radiation incident on the glazing surface are defined as follows:

Season	Dates	Value
Winter	Jan 1 - Mar 31, Nov 1 - Dec 31	50 Btu/hr-SF
Summer	May 1 - Oct 31	15 Btu/hr-SF

Infiltration schedule. The infiltration schedule is established from the fan system schedule. Infiltration is scheduled “off” when the fan system operated, and is scheduled “on” when the fan system is off.

Materials and Glazing Properties

Shell materials. A single-layer, homogeneous material is described which contains the conductance and heat capacity properties of the composite wall used in the building. The thermal conductance and heat capacity of each wall and roof assembly is taken from the Title 24 documents or building plans. The material properties representing each assembly are specified as summarized below:

Property	**Value**	**Comments**
Thickness	0.5 ft	Fixed for all materials
Conductivity	Wall conductance for as-built assembly from Title 24 documents	
Property	**Value**	**Comments**
Specific heat	0.2	Fixed for all materials
Absorptivity	0.7	Fixed for all constructions
Density	Calculated from heat capacity of as-built assembly from Title 24 documents	

If construction documents are not available, default values for the conductance and heat capacity are assigned from the wall and roof types specified in the on-site survey, and the observed R-values as shown in Table 1.

Table 1: Opaque Shell Construction Assumptions

		Assumed construction				Assumed R-values						Assumed Heat Capacity					Notes
Type Code	Opaque Surface Type	Layer 1	Layer 2	Layer 3	Layer 4	R1	R2	R3	R4	Rtot	U-value	HC1	HC2	HC3	HC4	HCtot	
1	Face Brick + Brick	4 in brick	4 in brick	no insul		0.56	0.56	0		1.12	**0.893**	8.4	8.4			**16.8**	
	+R-7	4 in brick	4 in brick	R-7	0.5" gyp bd	0.56	0.56	3.8	0.45	5.37	**0.186**	8.4	8.4	0.1	0.54	**17.4**	1
	+R-11	4 in brick	4 in brick	R-11	0.5" gyp bd	0.56	0.56	4.5	0.45	6.07	**0.165**	8.4	8.4	0.1	0.54	**17.4**	1
	+R-13	4 in brick	4 in brick	R-13	0.5" gyp bd	0.56	0.56	4.7	0.45	6.27	**0.159**	8.4	8.4	0.1	0.54	**17.4**	1
	+R-19	4 in brick	4 in brick	R-19	0.5" gyp bd	0.56	0.56	7	0.45	8.57	**0.117**	8.4	8.4	0.2	0.54	**17.5**	1
	+R-21	4 in brick	4 in brick	R-21	0.5" gyp bd	0.56	0.56	7.2	0.45	8.77	**0.114**	8.4	8.4	0.2	0.54	**17.5**	1
2	Face Brick + Poured Concrete	4 in brick	8 in NW conc	no insul		0.56	0.88	0		1.44	**0.694**	8.4	19.2			**27.6**	
	+R-7	4 in brick	8 in NW conc	R-7	0.5" gyp bd	0.56	0.88	3.8	0.45	5.69	**0.176**	8.4	19.2	0.1	0.54	**28.2**	1
	+R-11	4 in brick	8 in NW conc	R-11	0.5" gyp bd	0.56	0.88	4.5	0.45	6.39	**0.156**	8.4	19.2	0.1	0.54	**28.2**	1
	+R-13	4 in brick	8 in NW conc	R-13	0.5" gyp bd	0.56	0.88	4.7	0.45	6.59	**0.152**	8.4	19.2	0.1	0.54	**28.2**	1
	+R-19	4 in brick	8 in NW conc	R-19	0.5" gyp bd	0.56	0.88	7	0.45	8.89	**0.112**	8.4	19.2	0.2	0.54	**28.3**	1
	+R-21	4 in brick	8 in NW conc	R-21	0.5" gyp bd	0.56	0.88	7.2	0.45	9.09	**0.110**	8.4	19.2	0.2	0.54	**28.3**	1

Note 1: Metal framing assumed as furring material

Table 1: Opaque Shell Construction Assumptions (contd.)

		Assumed construction				Assumed R-values						Assumed Heat Capacity					Notes
Type Code	Opaque Surface Type	Layer 1	Layer 2	Layer 3	Layer 4	R1	R2	R3	R4	Rtot	U-value	HC1	HC2	HC3	HC4	HCtot	
3	Face Brick + Concrete Block	4 in brick	8 in NW block, no fill	no insul		0.56	1	0		1.56	**0.641**	8.4	11.1			**19.5**	
	+R-7	4 in brick	8 in NW block, no fill	R-7	0.5" gyp bd	0.56	1	3.8	0.45	5.81	**0.172**	8.4	11.1	0.1	0.54	**20.1**	1
	+R-11	4 in brick	8 in NW block, no fill	R-11	0.5" gyp bd	0.56	1	4.5	0.45	6.51	**0.154**	8.4	11.1	0.1	0.54	**20.1**	1
	+R-13	4 in brick	8 in NW block, no fill	R-13	0.5" gyp bd	0.56	1	4.7	0.45	6.71	**0.149**	8.4	11.1	0.1	0.54	**20.1**	1
	+R-19	4 in brick	8 in NW block, no fill	R-19	0.5" gyp bd	0.56	1	7	0.45	9.01	**0.111**	8.4	11.1	0.2	0.54	**20.2**	1
	+R-21	4 in brick	8 in NW block, no fill	R-21	0.5" gyp bd	0.56	1	7.2	0.45	9.21	**0.109**	8.4	11.1	0.2	0.54	**20.2**	1
4	Poured Concrete + Finish	stucco	8 in NW concrete	no insul		0.08	0.88	0		0.96	**1.042**	0.7	19.2			**19.9**	
	+R-7	stucco	8 in NW concrete	R-7	0.5" gyp bd	0.08	0.88	3.8	0.45	5.21	**0.192**	0.7	19.2	0.1	0.54	**20.6**	1
	+R-11	stucco	8 in NW concrete	R-11	0.5" gyp bd	0.08	0.88	4.5	0.45	5.91	**0.169**	0.7	19.2	0.1	0.54	**20.6**	1
	+R-13	stucco	8 in NW concrete	R-13	0.5" gyp bd	0.08	0.88	4.7	0.45	6.11	**0.164**	0.7	19.2	0.1	0.54	**20.6**	1
	+R-19	stucco	8 in NW concrete	R-19	0.5" gyp bd	0.08	0.88	7	0.45	8.41	**0.119**	0.7	19.2	0.2	0.54	**20.7**	1
	+R-21	stucco	8 in NW concrete	R-21	0.5" gyp bd	0.08	0.88	7.2	0.45	8.61	**0.116**	0.7	19.2	0.2	0.54	**20.7**	1

Note 1: Metal framing assumed as furring material

Table 1: Opaque Shell Construction Assumptions (contd.)

		Assumed construction				Assumed R-values						Assumed Heat Capacity					Notes
Type Code	Opaque Surface Type	Layer 1	Layer 2	Layer 3	Layer 4	R1	R2	R3	R4	Rtot	U-value	HC1	HC2	HC3	HC4	HCtot	
5	Concrete Block + Finish	stucco	8 in NW block, no fill	no insul		0.08	1	0		1.08	**0.926**	0.7	11.1			**11.8**	
	+R-7	stucco	8 in NW block, no fill	R-7	0.5" gyp bd	0.08	1	3.8	0.45	5.33	**0.188**	0.7	11.1	0.1	0.54	**12.5**	1
	+R-11	stucco	8 in NW block, no fill	R-11	0.5" gyp bd	0.08	1	4.5	0.45	6.03	**0.166**	0.7	11.1	0.1	0.54	**12.5**	1
	+R-13	stucco	8 in NW block, no fill	R-13	0.5" gyp bd	0.08	1	4.7	0.45	6.23	**0.161**	0.7	11.1	0.1	0.54	**12.5**	1
	+R-19	stucco	8 in NW block, no fill	R-19	0.5" gyp bd	0.08	1	7	0.45	8.53	**0.117**	0.7	11.1	0.2	0.54	**12.6**	1
	+R-21	stucco	8 in NW block, no fill	R-21	0.5" gyp bd	0.08	1	7.2	0.45	8.73	**0.115**	0.7	11.1	0.2	0.54	**12.6**	1
6	Wood Frame Wall																
	R-11	.5 in hb siding	.5 in pw sheath	R-11	0.5" gyp bd	0.5	0.62	8.75	0.56	10.43	**0.096**	0.84	0.41	1.27	0.54	**3.1**	2
	R-13	.5 in hb siding	.5 in pw sheath	R-13	0.5" gyp bd	0.5	0.62	10.15	0.56	11.83	**0.085**	0.84	0.41	1.27	0.54	**3.1**	2
	R-19	.5 in hb siding	.5 in pw sheath	R-19	0.5" gyp bd	0.5	0.62	15.025	0.56	16.705	**0.060**	0.84	0.41	2.102	0.54	**3.9**	3
	R-21	.5 in hb siding	.5 in pw sheath	R-21	0.5" gyp bd	0.5	0.62	16.425	0.56	18.105	**0.055**	0.84	0.41	2.102	0.54	**3.9**	3

Note 1: Metal framing assumed as furring material

Note 2: 2x4 construction , 16 in. O.C. assumed

Note 3: 2x6 construction, 24 in. O.C. assumed.

Table 1: Opaque Shell Construction Assumptions (contd.)

		Assumed construction				Assumed R-values						Assumed Heat Capacity					Notes
Type Code	Opaque Surface Type	Layer 1	Layer 2	Layer 3	Layer 4	R1	R2	R3	R4	Rtot	U-value	HC1	HC2	HC3	HC4	HCtot	
7	Metal Frame Wall																
	R-11	.5 in hb siding	.5 in pw sheath	R-11	0.5" gyp bd	0.5	0.62	4.433	0.56	6.113	**0.164**	0.84	0.41	1.27	0.54	**3.1**	1
	R-13	.5 in hb siding	.5 in pw sheath	R-13	0.5" gyp bd	0.5	0.62	4.706	0.56	6.386	**0.157**	0.84	0.41	1.27	0.54	**3.1**	1
	R-19	.5 in hb siding	.5 in pw sheath	R-19	0.5" gyp bd	0.5	0.62	7.125	0.56	8.805	**0.114**	0.84	0.41	2.102	0.54	**3.9**	2
	R-21	.5 in hb siding	.5 in pw sheath	R-21	0.5" gyp bd	0.5	0.62	7.308	0.56	8.988	**0.111**	0.84	0.41	2.102	0.54	**3.9**	2
8	Curtain Wall																
	R-7	Metal cladding	R-7	0.5" gyp bd		0.0004	4.039	0.56		4.6	**0.217**		0.1	0.54		**0.6**	3
	R-11	Metal cladding	R-11	0.5" gyp bd		0.0004	5.038	0.56		5.6	**0.179**		0.1	0.54		**0.6**	3
	R-13	Metal cladding	R-13	0.5" gyp bd		0.0004	5.395	0.56		6.0	**0.168**		0.1	0.54		**0.6**	3
	R-19	Metal cladding	R-19	0.5" gyp bd		0.0004	7.125	0.56		7.7	**0.130**		0.2	0.54		**0.7**	4
	R-21	Metal cladding	R-21	0.5" gyp bd		0.0004	7.308	0.56		7.9	**0.127**		0.2	0.54		**0.7**	4

Note 1: 2x4 construction, 16 in. O.C. assumed

Note 2: 2x6 construction, 24 in. O.C. assumed.

Note 3: 4 in steel member, 24 in OC assumed

Note 4: 6 in steel member, 24 in OC assumed

Table 1: Opaque Shell Construction Assumptions (contd.)

		Assumed construction			Assumed R-values					Assumed Heat Capacity				Notes
Type Code	Opaque Surface Type	Layer 1	Layer 2	Layer 3	R1	R2	R3	Rtot	U-value	HC1	HC2	HC3	HCtot	
9	Open								**2.7**				**0**	
10	Concrete Deck Roof.	Membrane		8 in LW conc	0.33		1.76	2.1	**0.478**	0.76		19.2	**20.0**	
	+R-5	Membrane	R-5	8 in LW conc	0.33	5	1.76	7.1	**0.141**	0.76	0.1	19.2	**20.1**	
	+R-10	Membrane	R-10	8 in LW conc	0.33	10	1.76	12.1	**0.083**	0.76	0.1	19.2	**20.1**	
	+R-15	Membrane	R-15	8 in LW conc	0.33	15	1.76	17.1	**0.059**	0.76	0.1	19.2	**20.1**	
	+R-20	Membrane	R-20	8 in LW conc	0.33	20	1.76	22.1	**0.045**	0.76	0.2	19.2	**20.2**	
	+R-25	Membrane	R-25	8 in LW conc	0.33	25	1.76	27.1	**0.037**	0.76	0.2	19.2	**20.2**	
	+R-30	Membrane	R-30	8 in LW conc	0.33	30	1.76	32.1	**0.031**	0.76	0.2	19.2	**20.2**	
	+R-35	Membrane	R-35	8 in LW conc	0.33	35	1.76	37.1	**0.027**	0.76	0.2	19.2	**20.2**	
	+R-40	Membrane	R-40	8 in LW conc	0.33	40	1.76	42.1	**0.024**	0.76	0.2	19.2	**20.2**	

Table 1: Opaque Shell Construction Assumptions (contd.)

		Assumed construction				Assumed R-values						Assumed Heat Capacity					Notes
Type Code	Opaque Surface Type	Layer 1	Layer 2	Layer 3	Layer 4	R1	R2	R3	R4	Rtot	U-value	HC1	HC2	HC3	HC4	HCtot	
11	Wood Frame Roof	Membrane	.75 PW	air layer	0.5" gyp	0.33	0.93	2.1	0.56	3.4	**0.298**	0.76	0.62	1.3	0.54	**3.2**	1
	+R-5	Membrane	.75 PW	R-5	0.5" gyp	0.33	0.93	5.7	0.56	7.0	**0.144**	0.76	0.62	1.4	0.54	**3.3**	1
	+R-10	Membrane	.75 PW	R-10	0.5" gyp	0.33	0.93	10.2	0.56	11.5	**0.087**	0.76	0.62	1.4	0.54	**3.3**	1
	+R-15	Membrane	.75 PW	R-15	0.5" gyp	0.33	0.93	14.7	0.56	16.0	**0.063**	0.76	0.62	1.4	0.54	**3.3**	1
	+R-20	Membrane	.75 PW	R-20	0.5" gyp	0.33	0.93	19.2	0.56	20.5	**0.049**	0.76	0.62	1.5	0.54	**3.4**	1
	+R-25	Membrane	.75 PW	R-25	0.5" gyp	0.33	0.93	23.7	0.56	25.0	**0.040**	0.76	0.62	1.5	0.54	**3.4**	1
	+R-30	Membrane	.75 PW	R-30	0.5" gyp	0.33	0.93	28.2	0.56	29.5	**0.034**	0.76	0.62	1.5	0.54	**3.4**	1
	+R-35	Membrane	.75 PW	R-35	0.5" gyp	0.33	0.93	32.7	0.56	34.0	**0.029**	0.76	0.62	1.5	0.54	**3.4**	1
	+R-40	Membrane	.75 PW	R-40	0.5" gyp	0.33	0.93	37.2	0.56	38.5	**0.026**	0.76	0.62	1.5	0.54	**3.4**	1
12	Metal Frame Roof	Membrane	.75 PW	air layer	0.5" gyp	0.33	0.93	1	0.56	2.3	**0.442**	0.76	0.62	0	0.54	**1.9**	2
	+R-5	Membrane	.75 PW	R-5	0.5" gyp	0.33	0.93	4.8	0.56	6.1	**0.165**	0.76	0.62	0.1	0.54	**2.0**	2
	+R-10	Membrane	.75 PW	R-10	0.5" gyp	0.33	0.93	9.2	0.56	10.5	**0.096**	0.76	0.62	0.1	0.54	**2.0**	2
	+R-15	Membrane	.75 PW	R-15	0.5" gyp	0.33	0.93	13.2	0.56	14.5	**0.069**	0.76	0.62	0.1	0.54	**2.0**	2
	+R-20	Membrane	.75 PW	R-20	0.5" gyp	0.33	0.93	17	0.56	18.3	**0.055**	0.76	0.62	0.2	0.54	**2.1**	2
	+R-25	Membrane	.75 PW	R-25	0.5" gyp	0.33	0.93	20.3	0.56	21.6	**0.046**	0.76	0.62	0.2	0.54	**2.1**	2
	+R-30	Membrane	.75 PW	R-30	0.5" gyp	0.33	0.93	23.7	0.56	25.0	**0.040**	0.76	0.62	0.2	0.54	**2.1**	2
	+R-35	Membrane	.75 PW	R-35	0.5" gyp	0.33	0.93	26.6	0.56	27.9	**0.036**	0.76	0.62	0.2	0.54	**2.1**	2
	+R-40	Membrane	.75 PW	R-40	0.5" gyp	0.33	0.93	29.2	0.56	30.5	**0.033**	0.76	0.62	0.2	0.54	**2.1**	2

Note 1: 2x12, 10% framing factor assumed

Note 2: Metal trusses, 4 ft OC assumed.

If the R-values are not observed during the on-site survey and the Title 24 documents or building plans are not available, the Title 24 U-value and heat capacity is used as a default. Opaque shell U-values are assigned based on the 1998 Title 24 requirements as a function of climate zone and heat capacity of the observed construction.

Building Shell Component	Overall U-Value				
	Climate Zones				
	1,16	2-5	6-10	11-13	14-15
Roof/Ceiling	0.057	0.057	0.078	0.057	0.057
Wall - Wood frame	0.084	0.092	0.092	0.084	0.084
Wall - Metal frame	0.182	0.189	0.189	0.182	0.182
Wall - Mass/ 7.0 ≤ HC < 15.0	0.340	0.430	0.430	0.430	0.430
Wall - Mass/ 15.0 ≤ HC	0.360	0.650	0.690	0.650	0.400
Wall - other	0.084	0.092	0.092	0.084	0.084
Floor/Soffit - Mass/ 7.0 ≤ HC	0.097	0.158	0.158	0.097	0.158

Note: these conductance values include the film coefficients

Windows. Window thermal and optical properties from the Title 24 documents or building plans are used to develop the DOE-2 inputs, as summarized below:

Glazing Property	Data Source	Comments
Glass conductance	Proposed window U-value from Title 24 or construction documents	Default values based on glass description used if documents not available
Shading coefficient	Proposed window solar heat gain coefficient from Title 24 or construction documents	Default values based on glass description used if documents not available. SHGC converted to SC for model.

If the Title 24 documents or other documentation are not available, default values for the glass conductance and shading coefficient are assigned as listed below, according to the glass type specified in the on-site survey.

Glass Type	Default SC
Single Pane Clear	0.94
Double Pane Clear	0.88
Triple Pane Clear	0.49
Single Pane Tint	0.72
Double Pane Tint	0.57
Triple Pane Tint	0.38

Glass Type	Default SC
Single Pane Reflective	0.38
Double Pane Reflective	0.30
Triple Pane Reflective	0.21
Single Pane Fritted	0.74
Double Pane Fritted	0.62
Triple Pane Fritted	0.51

Glass / Frame Type	Default U-Value
Single Pane, Standard Metal Frame	1.23
Single Pane, Thermal Break Metal Frame	1.1
Single Pane, Wood/Vinyl Frame	0.98
Double Pane, Standard Metal Frame	0.72
Double Pane, Thermal Break Metal Frame	0.59
Double Pane, Wood/Vinyl Frame	0.49
Triple Pane, Standard Metal Frame	0.42
Triple Pane, Thermal Break Metal Frame	0.36
Triple Pane, Wood/Vinyl Frame	0.32

Skylights. Skylight thermal and optical properties from the Title 24 documents or building plans are used to develop the DOE-2 inputs, as summarized below:

Glazing Property	Data Source	Comments
Glass conductance	Proposed skylight U-value from Title 24 or construction documents	Default values based on skylight description used if documents not available
Shading coefficient	Proposed skylight solar heat gain coefficient from Title 24 or construction documents	Default values based on skylight description used if documents not available. SHGC converted to SC for model.

If the Title 24 documents or other documentation are not available, default values for the glass conductance and shading coefficient are assigned as listed below, according to the skylight type specified in the on-site survey.

Skylight Type	Default SC
Single Pane Clear Glass	0.94
Double Pane Clear Glass	0.88
Triple Pane Clear Glass	0.49
Single Pane Tint Glass	0.72
Double Pane Tint Glass	0.57
Triple Pane Tint Glass	0.38
Single Pane Fritted	0.74
Double Pane Fritted	0.62
Triple Pane Fritted	0.51

Skylight Type	Default SC
Single Pane Clear Plastic	1.00
Double Pane Clear Plastic	0.89
Triple Pane Clear Plastic	0.75
Single Pane Tint Plastic	0.79
Double Pane Tint Plastic	0.67
Triple Pane Tint Plastic	0.57
Single Pane White Plastic	0.57
Double Pane White Plastic	0.49
Triple Pane White Plastic	0.41
Single Pane Translucent Plastic	0.26
Double Pane Translucent Plastic	0.23
Triple Pane Translucent Plastic	0.20

Glass / Frame Type	Default U-Value
Single Pane Glass, Standard Metal Frame w/o curb	1.36
Single Pane Glass, Standard Metal Frame w/ curb	1.98
Single Pane Glass, Thermal Break Metal Frame w/o curb	1.25
Single Pane Glass, Thermal Break Metal Frame w/ curb	1.89
Double Pane Glass, Standard Metal Frame w/o curb	0.81
Double Pane Glass, Standard Metal Frame w/ curb	1.31
Double Pane Glass, Thermal Break Metal Frame w/o curb	0.69
Double Pane Glass, Thermal Break Metal Frame w/ curb	1.10
Triple Pane Glass, Standard Metal Frame w/o curb	0.62
Triple Pane Glass, Standard Metal Frame w/ curb	1.12
Triple Pane Glass, Thermal Break Metal Frame w/o curb	0.51
Triple Pane Glass, Thermal Break Metal Frame w/ curb	0.87

Glass / Frame Type	Default U-Value
Single Pane Plastic, Standard Metal Frame w/o curb	1.21
Single Pane Plastic, Standard Metal Frame w/ curb	1.90
Single Pane Plastic, Thermal Break Metal Frame w/o curb	1.10
Single Pane Plastic, Thermal Break Metal Frame w/ curb	1.73
Double Pane Plastic, Standard Metal Frame w/o curb	0.81
Double Pane Plastic, Standard Metal Frame w/ curb	1.29
Double Pane Plastic, Thermal Break Metal Frame w/o curb	0.69
Double Pane Plastic, Thermal Break Metal Frame w/ curb	1.10
Triple Pane Plastic, Standard Metal Frame w/o curb	0.62
Triple Pane Plastic, Standard Metal Frame w/ curb	1.06
Triple Pane Plastic, Thermal Break Metal Frame w/o curb	0.51
Triple Pane Plastic, Thermal Break Metal Frame w/ curb	0.87

Interior walls. Interior walls are surveyed as either “air” or “solid.” Interior walls are modeled as shown in the Table below:

Interior wall Type	U-value	Notes
Air	2.7	Conductance for open space
Solid	0.10	Framed drywall interior wall assumed

SPACE-CONDITIONS

Space conditions are developed on a zone-by-zone basis. The DOE-2 input parameters considered, and the data sources are listed below. Schedules, which are developed on a zone-by-zone basis, are also associated with the appropriate zone.

DOE-2 input parameter	Data source	Comments
Number of people	Peak occupancy as surveyed.	
People sensible heat gain	250 Btu/hr-person	
People latent heat gain	250 Btu/hr-person	
Lighting kW	Fixture counts and fixture codes from on-site survey. Fixture connected loads as shown in Section 3.	Connected loads adjusted for the presence of lighting controls. See discussion below.
Light to space	= 0.45 for recessed fixtures = 1.0 for suspended and task	Value weighted by fixture connected load
Task Lighting kW	Fixture counts and fixture codes from on-site survey. Fixture connected loads as shown in Section 4.	
Equipment kW	Equipment counts and observed equipment connected loads from on-site survey. See below for more information.	Used for electric equipment in conditioned space. Input based on nameplate load. Nameplate data adjusted for actual running load using "rated-load factor." Equipment diversities included in schedule. See below for more information.
Source energy input	Equipment counts and observed equipment nameplate data from on-site survey. See below for more information.	Used for non-electric equipment in conditioned space. Nameplate data adjusted for actual running load using "rated-load factor." Equipment diversities included in schedule. See below for more information.
Equipment sensible heat gain	See discussion below	
Floor weight	70	Standard weighting factors used, medium construction
Infiltration rate	0.038 CFM / SF of exterior wall area	

Lighting controls. The presence of lighting controls is identified in the on-site survey. Depending on the control type, the impact of these controls on lighting consumption is simulated as either a reduction in connected load, or as a modification to the lighting schedule, as summarized below:

Lighting Controls	Simulation Approach
Occupancy sensor	Reduction in lighting power density of 20% for affected fixtures
Daylighting - continuous dimming	DOE-2 “function,” as described below.
Daylighting - stepped	DOE-2 “function,” as described below.
Lumen maintenance	Reduction in lighting power density of 10% for affected fixtures
Occupancy sensor plus daylighting	Reduction in lighting power density of 10% for affected fixtures, plus DOE-2 “function,” as described below.
Occupancy sensor plus lumen maintenance	Reduction in lighting power density of 37% for affected fixtures
Daylighting plus lumen maintenance	Reduction in lighting power density of 10% for affected fixtures, plus DOE-2 “function,” as described below.

Daylighting controls are simulated using the “functions” utility in the loads portion of DOE-2. Since the geometry of the zone is not fully described, it is not be possible to use the standard DOE-2 algorithms for simulating the daylighting illuminance in the space. A daylight factor, defined as the ratio of the interior illuminance at the daylighting control point to the global horizontal illuminance is estimated for each zone subject to daylighting control. The DOE-2 sky illuminance model calculates separate values for direct sun, clear sky, and overcast sky illuminance. The total exterior horizontal illuminance is simply the sum of each component:

$$I_{total} = I_{overcast} + I_{direct} + I_{clear}$$

Separate daylight factors are applied for overcast and clear sky sources. The fraction of the total illuminance that comes from the diffuse sky is calculated as follows:

$$f_{overcast} = \frac{I_{overcast}}{I_{total}}$$

The total interior illuminance at the control point is calculated from:

$$I_{interior} = I_{total} \times \left[f_{overcast} \times df_{overcast} + \left(1 - f_{overcast}\right) \times df_{clear} \right]$$

Default daylight factors are chosen to be typical of sidelighting applications in an enclosed office, as shown below. The values were developed from a set of Lumen-Micro simulations on a typical perimeter office space.

Illuminance Source	Daylight factor
Clear sky plus direct sun	0.18446
Diffuse sky	0.04252

The interior illuminance is calculated as described above using a DOE-2 “function.” Standard DOE-2 inputs for daylighting control specifications are used to simulate the impacts of daylighting controls on lighting schedules, as shown below:

DOE-2 input parameter	**Data source**	**Comments**
ZONE-FRACTION	On-site survey	Based on fraction of zone connected load controlled
LIGHT-SET-POINT	IES guidelines by occupancy type.	Occupancy type as listed in on-site survey
LIGHT-CTRL-TYPE	On-site survey	Stepped or continuous
LIGHT-CTRL-STEPS	1	On/off if stepped

The IES codes by occupancy type, and minimum illuminance setpoints are shown below:

CODE	Occupancy	IES category	Minimum illuminance (fc)
1	Auditorium	C	15
2	Churches/Chapels	D	30
3	Conventions, conference, meeting centers	D	30
4	Courtrooms	C	15
5	Exhibit	C	15
6	Main Entry Lobby	C	15
7	Motion Picture Theater	B	7.5
8	Performance theater	B	7.5
9	Bars, cocktail lounges, casinos	B	7.5
10	Dining	B	7.5
11	Kitchen	E	75
12	Bank/financial institution	D	30
13	Medical and clinical office (doctor	D	30
14	Office - Other	D	30
15	Computer Center	B	7.5

CODE	Occupancy	IES category	Minimum illuminance (fc)
16	EEG/EKG/RMI/Radiation	B	7.5
17	Emergency	E	75
18	General Area	D	30
19	Laboratory	E	75
20	Patient Room/ nursery	C	15
21	Occupational therapy/physical therapy	D	30
22	Pharmacy	E	75
23	Radiology	B	7.5
24	Recovery	E	75
25	Surgical & OB suite	F	150
26	Hotel Function	C	15
27	Hotel Guest Room	C	15
28	Hotel lobby	C	15
29	Barber, beauty shops	E	75
30	Bowling alley	N/A	10
31	Coin op laundry	D	30
32	Commercial dry cleaners	E	75
33	Grocery	E	75
34	Malls, Arcades, Atria	N/A	20
35	Retail sales, wholesale showrooms	N/A	75
36	Classrooms	E	75
37	Day Care	E	75
38	Dormitories	C	15
39	Gymnasiums	N/A	30
40	Library	E	75
41	Locker Room	C	15
42	School shops	D	30
43	Swimming pools	N/A	30
44	Aircraft hangers	N/A	75
45	Auto repair workshops	E	75
46	General commercial and industrial w	C	15
47	Precision commercial and/or industrial	E	75

CODE	Occupancy	IES category	Minimum illuminance (fc)
48	Storage, warehouse	B	7.5
49	Other spaces not listed	B	7.5

Equipment kW. Equipment connected loads represent all electrical loads in the conditioned space, which includes miscellaneous equipment and plug loads, kitchen equipment and refrigeration systems with integral condensers. Input data are based on the "nameplate" or total connected load. The nameplate data are adjusted using a "rated-load factor," which is the ratio of the average operating load to the nameplate load. This adjusted value represents the hourly running load of ***all*** equipment surveyed. Equipment diversity is accounted for in the schedule definition.

For the miscellaneous equipment and plug load category, equipment counts and connected loads are taken from the on-site survey. Where the connected loads are not observed, default values based on equipment type are used, as shown below:

Space Type	**Equipment Description**	**Default kW**	**Rated Load Factor**	**Notes**
General	Personal Computer w/ Monitor	0.5	0.25	
	Terminal	0.15	0.30	
	Laser Printer	0.85	0.15	
	Small Copier	0.77	0.15	
	Medium Copier	1.4	0.15	
	Large Copier	6.6	0.15	
	Fax Machine	0.1	0.15	
	Mini-Computer + Periph	1.0	0.35	
	Main Frame Computer + Periph		0.55	Must record kW
	Microwave	1.7	0.1	
	Misc. Appliance		0.20	Must record kW
	Television	0.15	0.60	
	Washer	0.5	0.20	
	Dryer	4.	1.0	
	Cash Register	0.15	0.30	
	Box Crusher	10.	0.02	
	Gasoline pump	0.7	0.10	
	ATM	0.5	0.3	

Space Type	Equipment Description	Default kW	Rated Load Factor	Notes
General	Video game	0.5	0.3	
	Excercise equipment	0.5	0.7	
Grocery	Meat Grinder	7.	0.05	
	Meat Saw	2.5	0.05	
	Meat Slicer	0.25	0.05	
	Wrapper	0.9	1.0	
	Check stand	1.5	0.10	
Hospital	Laboratory Equipment		0.30	Must record kW
	Monitoring, Life Support	1.1	0.50	
	EEG	1.1	0.50	
	EKG	1.1	0.50	
	MRI	26.	0.15	
	X-ray machine	5.	0.15	
	Radiation Therapy Machine	10.	0.15	
Industrial	Air Compressor		0.20	Must record kW
	Welder		0.20	Must record kW
	Battery Charger	1.5	0.30	
	Machine Tools		0.70	Must record kW
	Motor		0.60	Must record kW
Misc.	Other		0.15	Must record kW

For the kitchen equipment category, equipment counts and connected loads are taken from the on-site survey. Where the connected loads are not observed, default values based on equipment type and "trade size" are used, as shown below. Unlike the miscellaneous plug load schedules, the kitchen equipment schedules are defined by operating regime. An hourly value corresponding to "off", "idle", or "low," "medium," or "high" production rates are assigned by the surveyor. The hourly schedule is developed from the reported hourly operating status and the ratio of the hourly average running load to the connected load for each of the operating regimes.

Appliance Type Code	Appliance Description	Trade size	Default kW/unit	Ratio			
				Idle	Low	Medium	High
1	Broiler (including cheesemelter)	ft	1.7	0.17	0.25	0.30	0.35
2	Char Broiler	ft	3.7	0.60	0.70	0.80	0.90
3	Single sided griddle	ft	4.5	0.17	0.19	0.41	0.65
4	Clam shell griddle	ft	7.5	0.09	0.16	0.39	0.63
5	Countertop fryer	lb.	0.3	0.07	0.33	0.53	0.90
6	Free-standing fryer	lb.	0.3	0.07	0.33	0.53	0.90
7	Pressure fryer	lb.	0.3	0.07	0.33	0.53	0.90
8	Donut fryer	lb.	0.3	0.07	0.33	0.53	0.90
9	Kettle, Pasta cooker	qt	0.25	0.10	0.20	0.30	0.40
10	Heat lamps	no. lamps	0.5	1.0	1.0	1.0	1.0
11	Range top	ft	5.	0	0.20	0.40	0.60
12	Pizza or Bake Oven	no. decks	7.	0.10	0.20	0.30	0.40
13	Conveyor oven	no. decks	13.	0.10	0.20	0.30	0.40
14	Range Oven	ft	2.	0.10	0.20	0.30	0.40
15	Convection, combi, retherm oven, steamer	no. doors	3.8	0.10	0.20	0.30	0.40
16	Food warmer	ft	0.6	0.30	0.30	0.30	0.30
17	Heated display case	ft	0.5	0.50	0.50	0.50	0.50
18	Microwave oven	ea.	1.7	0.0	0.04	0.07	0.10
19	Pop-up Toaster	ea.	1.8	0.0	0.15	0.30	0.45
20	Conveyor Toaster	ea.	4.6	0.0	0.20	0.35	0.50
21	Coffee pot	burners	1.	0.30	0.30	0.30	0.30
22	Steam table	ft	0.6	0.30	0.30	0.30	0.30
23	Single Tank Dishwasher	racks/hr	0.3	0.10	0.30	0.40	0.50
24	Conveyor Dishwasher	racks/hr	0.1	0.10	0.30	0.40	0.50
25	Steam jacketed kettle	qt	0.4	0.15	0.20	0.40	0.60
26	Braising pan/skillet	qt	0.1	0.10	0.20	0.30	0.40

For the refrigeration equipment category, equipment type, count, and size are taken from the on-site survey. Equipment observed to have an "integral" compressor/condenser, that is, equipment that reject heat to the conditioned space, is assigned a connected load per unit size as shown below. For the refrigeration equipment listed, the default load is equal to the actual running load; thus the rated load factor is equal to 1.0.

Type Code	Case Description	Unit Dim.	Default kW/unit
1	Single-level narrow open island	ft	0.1
2	Single-level wide open island	ft	0.1
3	Single level double open island	ft	0.2
4	Single-level narrow closed island	ft	0.1
5	Single-level wide closed island	ft	0.1
6	Single level double closed island	ft	0.2
7	Open Single-deck	ft	0.3
8	Open Multi-deck	ft	0.3
9	Reach-in Multi deck	ft	0.1
10	Closed rear-entry multi-deck	ft	0.03
11	Curved glass rear entry multi deck	ft	0.06
12	Walk-in / Reach-in	ft	0.3
13	Walk-in	SF	0.015
14	Under counter Reach-in	CF	0.03
15	Blast Chiller	CF	0.03
16	Ice Maker	CF	0.15
17	Residential Reach-in Refrigerator/Freezer	CF	0.03
18	Residential Reach-in Freezer	CF	0.03
19	Residential Closed Coffin Freezer	CF	0.03
20	Refrigerated Vending Machine	CF	0.03
21	Water cooler	ea.	0.5
22	Slurpee, frappaccino machine	ea.	1.0
23	Other	kBtuh	

Source input energy. Source input energy represents all non-electric equipment in the conditioned space. In the model, the source type is set to natural gas, and a total input energy is specified in terms of Btu/hr. Sources of internal heat gains to the space that were not electrically-powered include kitchen equipment, and dryers and other miscellaneous process loads. The input rating of the equipment is entered by the surveyors. As with the electrical equipment, the ratio of the rated input energy to the actual hourly consumption is calculated by the rated load factor assigned by equipment type and operating regime. Default values for gas equipment input ratings are used as shown below:

Appliance Type Code	Appliance Description	Trade size	Default Btu/hr input /unit
1	Broiler (including cheesemelter)	ft	10,000
2	Char Broiler	ft	25,000
3	Single sided griddle	ft	30,000
4	Clam shell griddle	ft	40,000
5	Countertop fryer	lb.	2,500
6	Free-standing fryer	lb.	2,500
7	Pressure fryer	lb.	1,800
8	Donut fryer	lb.	700
9	Kettle, Pasta cooker	qt	1,600
10	Heat lamps	no. lamps	N/A
11	Range top	ft	25,000
12	Pizza or Bake Oven	no. decks	65,000
13	Conveyor oven	no. decks	133,000
14	Range Oven	ft	12,000
15	Convection, combi, retherm oven, steamer	no. doors	35,000
16	Food warmer	ft	1,000
17	Heated display case	ft	N/A
18	Microwave oven		N/A
19	Pop-up Toaster		N/A
20	Conveyor Toaster		N/A
21	Coffee pot	burners	N/A
22	Steam table	ft	N/A
23	Single Tank Dishwasher	racks/hr	400
24	Conveyor Dishwasher	racks/hr	400
25	Steam jacketed kettle	qt	2,000
26	Braising pan/skillet	qt	900

Heat gains to space. The heat gains to space are calculated based on the actual running loads and an assessment of the proportion of the input energy that contributes to sensible and latent heat gains. This in turn depends on whether or not the equipment is located under a ventilation hood.

For miscellaneous equipment and plug loads where equipment is not located under a hood, 100 percent of the equipment energy is directed to the space, and the sensible heat gain fraction is set at 1.0. For miscellaneous equipment and plug loads where equipment was located under a hood, 30 percent of the equipment energy is directed to the space, and the sensible heat gain fraction is set at 1.0. Similarly, for refrigeration equipment with integral compressor condensers, 100 percent of the input energy is directed to the conditioned space and the sensible heat gain fraction is set at 1.0. For kitchen equipment, the heat gain multipliers are set as follows:

Code	Appliance	Electric				Gas			
		Hood		No Hood		Hood		No Hood	
		Sens	Lat	Sens	Lat	Sens	Lat	Sens	Lat
1	Broiler (including cheesemelter)	1.00	0.00	N/A	N/A	0.56	0.00	N/A	N/A
2	Char Broiler	0.34	0.00	N/A	N/A	0.16	0.00	N/A	N/A
3	Single sided griddle	0.37	0.00	N/A	N/A	0.32	0.00	N/A	N/A
4	Clam shell griddle	0.44	0.00	N/A	N/A	0.38	0.00	N/A	N/A
5	Countertop fryer	0.09	0.00	N/A	N/A	0.06	0.00	N/A	N/A
6	Free-standing fryer	0.09	0.00	N/A	N/A	0.06	0.00	N/A	N/A
7	Pressure fryer	0.09	0.00	N/A	N/A	0.06	0.00	N/A	N/A
8	Donut fryer	0.09	0.00	N/A	N/A	0.06	0.00	N/A	N/A
9	Kettle, Pasta cooker	0.20	0.00	N/A	N/A	0.15	0.00	N/A	N/A
10	Heat lamps	N/A	0.00	1.00	0.00	N/A	0.00	1.00	0.00
11	Range top	0.80	0.00	N/A	N/A	0.30	0.00	N/A	N/A
12	Pizza or Bake Oven	0.35	0.00	N/A	N/A	0.40	0.00	N/A	N/A
13	Conveyor oven	0.35	0.00	N/A	N/A	0.40	0.00	N/A	N/A
14	Range Oven	0.35	0.00	N/A	N/A	0.40	0.00	N/A	N/A
15	Convection, combi, retherm oven, steamer	0.35	0.00	N/A	N/A	0.40	0.00	N/A	N/A
16	Food warmer	0.53	0.00	0.67	0.33	N/A	0.00	N/A	N/A
17	Heated display case	N/A	0.00	1.00	0.00	N/A	0.00	N/A	N/A
18	Microwave oven	N/A	0.00	1.00	0.00	N/A	0.00	N/A	N/A
19	Pop-up Toaster	1.00	0.00	1.00	1.00	N/A	0.00	N/A	N/A
20	Conveyor Toaster	0.80	0.00	1.00	1.00	N/A	0.00	N/A	N/A
21	Coffee pot	N/A	0.00	1.00	1.00	N/A	0.00	N/A	N/A
22	Steam table	1.00	0.00	1.00	1.00	N/A	0.00	N/A	N/A
23	Single Tank Dishwasher	0.40	0.00	0.25	0.75	N/A	0.00	N/A	N/A

Code	Appliance	Electric				Gas			
		Hood		No Hood		Hood		No Hood	
		Sens	Lat	Sens	Lat	Sens	Lat	Sens	Lat
24	Conveyor Dishwasher	0.40	0.00	0.25	0.75	N/A	0.00	N/A	N/A
25	Steam jacketed kettle	0.20	0.00	N/A	N/A	0.15	0.00	N/A	N/A
26	Braising pan/skillet	0.25	0.00	N/A	N/A	0.20	0.00	N/A	N/A

Space

Each space in the DOE-2 model corresponds to a zone defined in the on-site survey. Each survey zone can consist of multiple survey "spaces." The space conditions parameters developed on a zone by zone basis are included in the description of each space. Enclosing surfaces, as defined by the on-site surveyors, are also defined. The DOE-2 input parameters considered, and their associated data sources are listed as follows:

General Parameters

DOE-2 input parameter	**Data source**	**Comments**
Zone type	Conditioned	Only conditioned zones surveyed for this project
Area	On-site survey	
Volume	Floor area, average wall height from on-site survey	
Space conditions	Space conditions as defined above.	

Exterior Walls

DOE-2 input parameter	**Data source**	**Comments**
Wall height	On-site survey	Height is defined as space enclosed by insulation, including plenum if insulation is located at roof level. Plenums surveyed separately if insulation is at ceiling level
Wall width	On-site survey	
Wall construction	Construction as defined in section 2.1.3 above.	
Wall azimuth	Surface orientation, from on-site survey	Limited to N, NE, E, SE, S, SW, W, NW.
Tilt	90 degrees	Constant
Window height	On-site survey	Associated to wall surface based on surveyed orientation.
Window width	On-site survey	

DOE-2 input parameter	Data source	Comments
Window thermal and optical properties	Window properties as defined in section 2.1.3 above.	
OVERHANG-A	Overhang offset from survey	
OVERHANG-B	0	Constant
OVERHANG-D	Overhang projection, on-site survey	
OVERHANG-W	Overhang width, on-site survey	
Shading schedules	Schedules as defined in section 2.1.4 above	

Roof Parameters

DOE-2 input parameter	Data source	Comments
Roof height	On-site survey	
Roof width	On-site survey	
Roof construction	Construction as defined in section 2.1.3 above.	
Roof tilt	On-site survey	
Roof azimuth	Surface orientation, from on-site survey	Limited to N, NE, E, SE, S, SW, W, NW. Not relevant if tilt is zero.
Skylight height	On-site survey	
Skylight width	On-site survey	
Skylight tilt	On-site survey	Same as associated roof suface
Skylight azimuth	Skylight orientation, from on-site survey	Same as associated roof suface
Skylight thermal and optical properties	Window properties as defined in section 2.1.3 above.	
Shading schedules	Schedules as defined in section 2.1.4 above	

Plenums

A separate plenum zone is created for each surveyed zone when plenums are surveyed. The plenum wall construction is assumed to be the same as the walls enclosing the conditioned space, but the plenum wall R-value can be assigned uniquely. The ceiling insulation (if any) R-value is also assigned by the surveyor.

SYSTEMS

This section describes the methodology used to develop DOE-2 input for the systems simulation. Principal data sources include the on-site survey, Title 24 documents, manufacturers' data, and other engineering references as listed in this section.

Throughout the systems simulation, input power for pumps, fans and other motor-driven equipment is required. Most motor nameplate data are listed in terms of rated shaft horsepower. Thus, a conversion from motor hp to input power is required. The general equation used to perform this conversion is listed below:

$$kW = \frac{hp \times 0.746}{\eta_{motor}}$$

where:

kW = input power

hp = nameplate motor hp

η_{motor} = motor efficiency

The motor efficiency is generally a function of the motor hp. Motor efficiencies as observed by the surveyors are used to calculate input power. In the absence of motor efficiency observations, efficiencies are assigned as shown below:

Single Phase Motors

hp	Efficiency
0.50	70
0.75	72
1.00	79
1.50	80
2.00	80

hp	Efficiency
3.00	81
5.00	82
7.50	85
10.00	85

Three Phase Motors

hp	Efficiency
1.00	79
1.50	80
2.00	80
3.00	81
5.00	82
7.50	85
10.00	85
15.00	86
20.00	87
25.00	88

hp	Efficiency
30.00	89
40.00	89
50.00	89
60.00	89
75.00	90
100.00	90
125.00	90
150.00	91
200.00	91

SCHEDULES

Schedules were created from the responses to the interview portion of the on-site survey. Four types of schedules were defined:

- Fan operating hours
- Heating / cooling availability
- Thermostat setpoint
- Exterior lighting

The implementation of the schedules in DOE-2 is summarized below:

DOE-2 input parameter	**Data source**	**Comments**
Fan on/off	On-site survey	See discussion below
Heating / cooling availability	Always on	
Thermostat setpoint	On-site survey	No monthly adjustments
Exterior lighting	On-site survey	See discussion below

Fan schedules. Each day of the week is assigned to a particular daytype, as reported by the surveyor. The fan system on and off times from the on-site survey are assigned to a schedule according to daytype. These values are modified on a monthly basis, according to the monthly HVAC operating hour adjustment. The on and off times were adjusted equally until the required adjustment percentage is achieved. For example, if the original schedule is "on" at 6:00 hours and "off" at 18:00 hours, and the monthly HVAC adjustment indicates that HVAC operates at 50% of normal in June, then the operating hours are reduced by 50% by moving the "on" time up to 9:00 hours and the "off" time back to 15:00 hours. Surveyed fan schedules are verified by short-term monitoring of the HVAC unit. The night cycle controls are set to "stay-off," or "cycle on any," according to the operation observed by short-term monitoring of the HVAC system.

Setback schedules. Similarly, thermostat setback schedules are created based on the responses to the on-site survey. Each day of the week is assigned to a particular daytype. The thermostat setpoints for heating and cooling, and the setback temperatures and times are defined according to the survey responses. The return from setback and go to setback time are modified on a monthly basis in the same manner as the fan operating schedule. Surveyed thermostat schedules are verified by short-term monitoring of the room temperature near the thermostat.

Supply air reset schedule. If the interview indicates that a supply air reset control strategy is used, the reset schedule is defined according to the rules set forth in the 1998 ACM manual:

SUPP-AIR-SCH = DAY-RESET-SCH

SUPPLY-HI = [SUPPLY-LOW + 5]

SUPPLY-LO = [greater of SAT and 50]

OUTSIDE-HI = [SUPPLY-HI]

OUTSIDE-LO = [SUPPLY-LO]

Zone-level HVAC System Specifications

The following assumptions are used to develop the zone-level HVAC system specifications for the DOE-2 model:

DOE-2 input parameter	Data source	Comments
Design heat temperature	Heating setpoint + 2°F	
Design cool temperature	Cooling setpoint - 2°F	
Outside air CFM	Outdoor air CFM per SF, based on occupancy code and 15 CFM / person or observed outdoor air fraction from survey or short-term monitoring	See below
Exhaust CFM	Kitchen hood exhaust flow	Sum of all entries
Exhaust kW	Kitchen hood exhaust fan hp	Sum of all entries
Sizing option	Adjust loads	

Ventilation Rate Assumptions Based on Occupancy Code

CODE	Occupancy	Occupants / 1000 SF	SOURCE	Occupants / SF	OA CFM / SF
1	Auditorium	71	CEC	0.0710	1.065
2	Churches/Chapels	71	CEC	0.0710	1.065
3	Conventions, conference, meeting centers	35	CEC	0.0350	0.525
4	Courtrooms	71	CEC	0.0710	1.065
5	Exhibit	35	CEC	0.0350	0.525
6	Main Entry Lobby	35	CEC	0.0350	0.525
7	Motion Picture Theater	71	CEC	0.0710	1.065
8	Performance theater	71	CEC	0.0710	1.065
9	Bars, cocktail lounges, casinos	35	CEC	0.0350	0.525
10	Dining	35	CEC	0.0350	0.525
11	Kitchen	5	CEC	0.0050	0.075
12	Bank/financial institution	13	CEC	0.0130	0.195
13	Medical and clinical office (doctor, dentist, etc.)	10	CEC	0.0100	0.15
14	Office - Other	7	CEC	0.0070	0.105
15	Computer Center	60	ASHRAE 62-89	0.0600	0.9
16	EEG/EKG/RMI/Radiation	20	ASHRAE 62-89	0.0200	0.3
17	Emergency	20	ASHRAE 62-89	0.0200	0.3

CODE	Occupancy	Occupants / 1000 SF	SOURCE	Occupants / SF	OA CFM / SF
18	General Area	20	ASHRAE 62-89	0.0200	0.3
19	Laboratory	20	ASHRAE 62-89	0.0200	0.3
20	Patient Room/ nursery	10	ASHRAE 62-89	0.0100	0.15
21	Occupational therapy/physical therapy	20	ASHRAE 62-89	0.0200	0.3
22	Pharmacy	20	ASHRAE 62-89	0.0200	0.3
23	Radiology	20	ASHRAE 62-89	0.0200	0.3
24	Recovery	20	ASHRAE 62-89	0.0200	0.3
25	Surgical & OB suite	20	ASHRAE 62-89	0.0200	0.3
26	Hotel Function	71	CEC	0.0710	1.065
27	Hotel Guest Room	3	CEC	0.0030	0.045
28	Hotel lobby	35	CEC	0.0350	0.525
29	Barber, beauty shops	10	CEC	0.0100	0.15
30	Bowling alley	70	ASHRAE 62-89	0.0700	1.05
31	Coin op laundry	10	CEC	0.0100	0.15
32	Commercial dry cleaners	15	CEC	0.0150	0.225
33	Grocery	17	CEC	0.0170	0.255
34	Malls, Arcades, Atria	17	CEC	0.0170	0.255
35	Retail sales, wholesale showrooms	13	CEC	0.0130	0.195
36	Classrooms	25	CEC	0.0250	0.375
37	Day Care	25	CEC	0.0250	0.375
38	Dormitories	20	ASHRAE 62-89	0.0200	0.3
39	Gymnasiums	30	ASHRAE 62-89	0.0300	0.45
40	Library	20	CEC	0.0200	0.3
41	Locker Room	33	ASHRAE 62-89	0.0330	0.495
42	School shops	30	CEC	0.0300	0.45
43	Swimming pools	33	ASHRAE 62-89	0.0330	0.495
44	Aircraft hangers	5	CEC	0.0050	0.075
45	Auto repair workshops	5	CEC	0.0050	0.075
46	General commercial and industrial work	10	CEC	0.0100	0.15
47	Precision commercial and/or industrial work	10	CEC	0.0100	0.15
48	Storage, warehouse	2	CEC	0.0020	0.03
49	Other spaces not listed	4	CEC	0.0040	0.06

Zone-level HVAC Controls

Zone-level HVAC control specifications are defined as summarized below:

DOE-2 input parameter	**Data source**	**Comments**
Cooling setpoint schedule	As defined in section 2.2.1	
Heating setpoint schedule	As defined in section 2.2.1	
Thermostat type	Reverse action	
Throttling range	2°F	

HVAC System Type

The HVAC system type is defined as packaged single zone "PSZ" for all systems modeled for this project.

HVAC System Specifications

HVAC system design and performance specifications are developed as shown below:

DOE-2 input parameter	Data source	Comments
Supply air CFM	Manufacturers' data	Default value of 400 CFM/ton used.
Supply fan kW	Spot metering of fan kW	If unknown, set to 0.000375kW/CFM
Supply fan delta T	Use "0" for packaged systems	Packaged system capacities are "net" after fan heat.
Return fan kW	Spot metering of fan kW	If unknown, set to 0
DOE-2 input parameter	**Data source**	**Comments**
Cooling capacity	Manufacturers' data	Based at ARI rating point
Cooling efficiency	Manufacturers' data adjusted for fan energy. See discussion below.	
Heating capacity	Manufacturers' data	
Heating efficiency	Manufacturers' data	
Supplemental heat capacity	Not specified	Use DOE-2 self-sized capacity
Supplemental heat source	Set to "electric."	

Packaged HVAC system efficiency. Manufacturers' data on packaged system efficiency is a net efficiency, which considers both fan and compressor energy. DOE-2 requires a specification of packaged system efficiency that considers the compressor efficiency only. Since fan power in DOE-2 is calculated separately, the manufacturers' data need to be adjusted to prevent "double-counting" of fan energy. Algorithms set forth in the 1998 ACM are used to calculate the DOE-2 E-I-R from manufacturers' EER and COP.

HVAC system controls

HVAC system control specifications are developed as shown below:

DOE-2 input parameter	Data source	Comments
Max supply air temp	100°F	Constant
Minimum supply air temp	On-site survey	55°F if unknown
Economizer high limit temp	Onsite survey	Varies based on observed economizer controller setpoint. See below
Economizer lockout	Onsite survey	Varies based on system size
Outdoor air control	On-site survey, as listed for each system	Fixed, single point temperature, differential temperature, single point enthalpy, differential enthalpy
Supply air temperature reset control (cooling mode)	On-site survey. Use "warmest" if response is "zone temp," "reset" if response is "outside temp."	Reset schedule defined in section 2.2.1 above.
Preheat coil setpoint	-50°F	Assume no preheat
Fan schedule	As defined in section 2.2.1	
Fan control	On-site survey, as defined for each system type	
Night cycle control	Onsite survey	"Stay off" or "cycle on any"
Defrost type	Set to "electric."	Heat pump only
Defrost control	On-demand	Heat pump only.

Economizer high limit setpoints are specified based on the controller setpoint observed in the field. For Honeywell controllers, the setpoint is designated by an A, B, C or D setting on the controller. The DOE-2 model specifications for each of these setpoint choices is shown below:

Honeywell Controller Setting	Enthalpy Limit	Drybulb Limit
A	28.0 Btu/lb	78°F
B	25.0 Btu/lb	74°F
C	22.0 Btu/lb	68°F
D	20.0 Btu/lb	63°F

Duct losses are modeled only in buildings where the ducts are located in an unconditioned space or outdoors. The losses are modeled using the following DOE-2 commands:

DOE-2 input parameter	Data source	Comments
DUCT-AIR-LOSS	Defaults to 36% total leakage, split evenly between supply and return systems	Not measured; default values based on Modera and Proctor study.
DUCT-UA	Onsite survey	Supply duct area and duct insulation R-values are summed for each supply duct entry. Supply losses only modeled by DOE-2.2
DUCT-AIR-LOSS-OA	Onsite survey	Set to 0.0 for ducts located in an unconditioned plenum; set to 1.0 for ducts located outdoors
DUCT-ZONE	Defaults to plenum zone assigned to thermal zone conditioned by each system	A separate plenum is assigned to each system, as required by DOE-2.2.

Refrigeration Systems.

Detailed simulation of refrigeration systems is done for all commercial buildings with remote refrigeration condensers. Refrigeration cases are grouped into three systems which are defined by their operating temperature: ice cream cases, frozen food cases, and all others. For each operating temperature, the following input data are defined:

DOE-2 input parameter	Data source	Comments
Refrigeration zone load	Function of case type and product code. Manufacturers' or program data used when available. See below for default values	Total load calculated from unit load, size and quantity. Not used for walk-in cases. Case performance data abstracted from Hussman catalog.
Refrigeration zone sensible heat ratio	0.8	Default
Refrigeration supply air discharge temp	Function of case type and product code. Temperature defined according to surveyed case lineup and standard values as shown below.	Weighted average of all cases in lineup used.
Refrigeration evaporator temperature	Function of case type and product code. Temperature defined according to surveyed case lineup and standard values as shown below.	Minimum value of all cases in lineup used.
Refrigeration auxiliary kW	Function of case type and product code. Temperature defined according to surveyed case lineup and standard values as shown below.	

DOE-2 input parameter	**Data source**	**Comments**
Refrigeration auxiliary heat	Function of case type and product code. Loads defined according to surveyed case lineup and standard values as shown below.	Used for walk-in cases only
Refrigeration defrost mechanism	On-site survey	Use "Elec" if unknown
Refrigeration defrost control	Timer	Default

Zone loads for reach-in cases are based on standard 2-pane glass doors. The zone loads are modified based on the door type surveyed as follows:

Door Type	Zone Load Multiplier
Single pane	2.1
Double pane	1.0
Triple pane	0.73
Quadruple pane	0.50

Case Type	Product Stored	Case Specifications			
		Zone Load (Btu/hr-ft)	Elec Aux (W/ft)	Supply Air Temp (°F)	Evap Surf Temp (°F)
Single-level narrow open island	Ice Cream	322.0	25.0	-20.0	-30.0
Single-level narrow open island	Frozen Food	238.0	25.0	-10.0	-20.0
Single-level narrow open island	Fresh Meat	190.0	21.0	24.0	18.0
Single-level narrow open island	Deli	190.0	21.0	30.0	23.0
Single-level narrow open island	Dairy/Beverage	190.0	21.0	24.0	18.0
Single-level narrow open island	Produce	190.0	21.0	34.0	20.0
Single-level wide open island	Ice Cream	644.0	40.0	-20.0	-30.0
Single-level wide open island	Frozen Food	476.0	40.0	-10.0	-20.0
Single-level wide open island	Fresh Meat	380.0	42.0	24.0	18.0
Single-level wide open island	Deli	380.0	42.0	30.0	23.0
Single-level wide open island	Dairy/Beverage	380.0	42.0	24.0	18.0
Single-level wide open island	Produce	380.0	42.0	34.0	20.0
Single level double open island	Ice Cream	644.0	50.0	-20.0	-30.0
Single level double open island	Frozen Food	476.0	50.0	-10.0	-20.0
Single level double open island	Fresh Meat	380.0	42.0	24.0	18.0
Single level double open island	Deli	380.0	42.0	30.0	23.0
Single level double open island	Dairy/Beverage	380.0	42.0	24.0	18.0
Single level double open island	Produce	380.0	42.0	34.0	20.0
Single-level narrow closed island	Ice Cream	213.0	25.0	-20.0	-30.0
Single-level narrow closed island	Frozen Food	110.0	25.0	-10.0	-20.0
Single-level narrow closed island	Fresh Meat	92.0	39.0	24.0	18.0
Single-level narrow closed island	Deli	380.0	39.0	30.0	23.0
Single-level narrow closed island	Dairy/Beverage	92.0	39.0	24.0	18.0

Case Type	Product Stored	Case Specifications			
		Zone Load (Btu/hr-ft)	Elec Aux (W/ft)	Supply Air Temp (°F)	Evap Surf Temp (°F)
Single-level narrow closed island	Produce	190.0	39.0	34.0	20.0
Single-level wide closed island	Ice Cream	427.0	40.0	-20.0	-30.0
Single-level wide closed island	Frozen Food	220.0	40.0	-10.0	-20.0
Single-level wide closed island	Fresh Meat	184.0	76.0	24.0	18.0
Single-level wide closed island	Deli	184.0	76.0	30.0	23.0
Single-level wide closed island	Dairy/Beverage	184.0	76.0	24.0	18.0
Single-level wide closed island	Produce	380.0	76.0	34.0	20.0
Single level double closed island	Ice Cream	427.0	50.0	-20.0	-30.0
Single level double closed island	Frozen Food	220.0	50.0	-10.0	-20.0
Single level double closed island	Fresh Meat	184.0	76.0	24.0	18.0
Single level double closed island	Deli	184.0	76.0	30.0	23.0
Single level double closed island	Dairy/Beverage	184.0	76.0	24.0	18.0
Single level double closed island	Produce	380.0	76.0	34.0	20.0
Single Deck	Ice Cream	1167.0	218.0	-20.0	-30.0
Single Deck	Frozen Food	880.0	121.0	-10.0	-20.0
Single Deck	Fresh Meat	357.0	17.0	22.0	17.0
Single Deck	Deli	252.0	17.0	30.0	25.0
Single Deck	Dairy/Beverage	542.0	17.0	39.0	23.0
Single Deck	Produce	542.0	17.0	39.0	23.0
Open Multi-deck	Ice Cream	1167.0	218.0	-20.0	-30.0
Open Multi-deck	Frozen Food	880.0	121.0	-10.0	-20.0
Open Multi-deck	Fresh Meat	1339.0	50.0	23.0	14.0
Open Multi-deck	Deli	1371.0	48.0	31.0	19.0
Open Multi-deck	Dairy/Beverage	1313.0	33.0	32.0	21.0
Open Multi-deck	Produce	1178.0	39.0	34.0	20.0
Reach-in Multi deck	Ice Cream	148.0	137.0	-12.0	-19.0
Reach-in Multi deck	Frozen Food	118.0	132.0	-5.0	-11.0
Reach-in Multi deck	Fresh Meat	229.0	86.0	24.0	21.0
Reach-in Multi deck	Deli	229.0	86.0	30.0	23.0
Reach-in Multi deck	Dairy/Beverage	72.0	86.0	34.0	27.0
Reach-in Multi deck	Produce	72.0	86.0	36.0	22.0
Closed rear-entry multi-deck	Ice Cream	148.0	137.0	-12.0	-18.0
Closed rear-entry multi-deck	Frozen Food	117.0	132.0	-5.0	-11.0
Closed rear-entry multi-deck	Fresh Meat	305.0	43.0	24.0	21.0
Closed rear-entry multi-deck	Deli	242.0	66.0	30.0	23.0
Closed rear-entry multi-deck	Dairy/Beverage	72.0	86.0	34.0	27.0
Closed rear-entry multi-deck	Produce	72.0	86.0	36.0	22.0
Curved glass rear entry multi deck	Ice Cream	148.0	137.0	-12.0	-18.0
Curved glass rear entry multi deck	Frozen Food	117.0	132.0	-5.0	-11.0
Curved glass rear entry multi deck	Fresh Meat	305.0	43.0	24.0	21.0
Curved glass rear entry multi deck	Deli	242.0	66.0	26.0	22.0
Curved glass rear entry multi deck	Dairy/Beverage	72.0	86.0	34.0	27.0
Curved glass rear entry multi deck	Produce	72.0	86.0	36.0	22.0

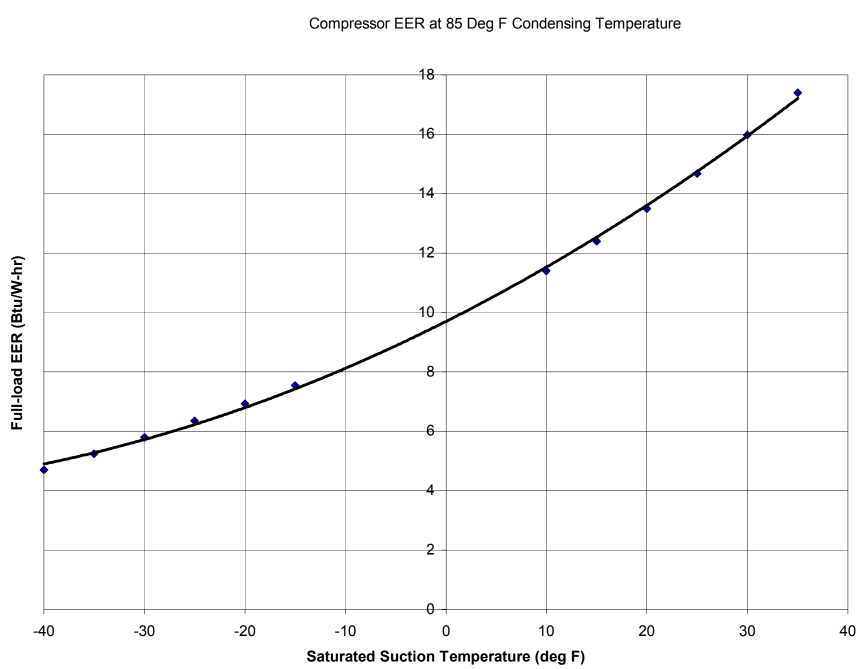
Case Type	Product Stored	Case Specifications			
		Case Load (Btu/hr-SF)	Elec Aux (W/SF)	Supply Air Temp (°F)	Evap Surf Temp (°F)
Walk-in	Ice Cream	65.0	2.0	-10.0	-20.0
Walk-in	Frozen Food	65.0	2.0	-10.0	-20.0
Walk-in	Fresh Meat	55.0	1.0	24.0	18.0
Walk-in	Deli	55.0	1.0	30.0	23.0
Walk-in	Dairy/Beverage	52.0	1.0	33.0	27.0
Walk-in	Produce	50.0	1.0	40.0	22.0

Note: Walk-in / Reach-in cases sum zone load, case load, and auxiliary electric data for Reach-in (LF) and Walk-in (SF) components.

In addition to the refrigerated casework data specified above, general data on the refrigeration compressor plant is specified for all compressors in the system:

DOE-2 input parameter	**Data source**	**Comments**
Refrigeration sizing ratio	1.2	Constant
Refrigeration compressor efficiency	Default value, based on case temperature	DOE-2 requires EER data at 85°F condensing temperature. .

Compressor efficiency is specified at full load, with a condensing temperature of 85°F and a saturated suction temperature (SST) equal to the evaporator temperature defined by each case lineup. Default values are shown below:



DOE-2 input parameter	Data source	Comments
Refrigeration condenser fan kW	Default	
Minimum condensing temperature	82 deg F	
Refrigeration condenser type	Air	
Condenser fan control	On-site survey	1 speed,.
Nominal condenser capacity	Self-sized	

HVAC System Sizing

HVAC system sizing for the as-built case is determined by direct observation of the nameplate capacities of the HVAC equipment. The installed HVAC system capacity is compared to the design loads imposed on the system to determine a sizing ratio for the as-built building. The design cooling loads are calculated from a design-day simulation. The specification of the design-day simulation is described below:

DOE-2 input parameter	Data source	Comments
Run period	Sep 1 through Sep 8	
Clearness	1.0	Same for heating and cooling
Cloud amount	0.0	Same for heating and cooling
Cloud type	Cirrus	
Daily maximum drybulb temp	Summer design drybulb temperature for particular location.	
Daily maximum dewpoint temp	Summer design wet bulb temperature for particular location, converted to dewpoint	
Hour of maximum temperature	16:00	
Hour of minimum temperature	04:00	
Diurnal temperature swing	10 °F	
Wind speed	0	
Lighting, equipment, and occupancy schedules	Schedules set to 1 for all hours	
Window shading schedules	Windows unshaded for all hours.	

LIGHTING FIXTURE CODES AND FIXTURE WATTS ASSUMPTIONS

The following tables show the assumptions used for fixture watts:

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
F21LL	2	1	T8	F17T8	Fluorescent, (1) 24", T-8 lamp	17	Electronic	22
F21LE	2	1	T8	F17T8	Fluorescent, (1) 24", T-8 lamp	17	Mag-ES	23
F21SS	2	1	T12	F20T12	Fluorescent, (1) 24", STD lamp	20	Mag-STD	25
F21HS	2	1	T12	F24T12/HO	Fluorescent, (1) 24", HO lamp	35	Mag-STD	53
F22LL	2	2	T8	F17T8	Fluorescent, (2) 24", T-8 lamp	17	Electronic	34
F22LE	2	2	T8	F17T8	Fluorescent, (2) 24", T-8 lamp	17	Mag-ES	45
F22SS	2	2	T12	F24T12	Fluorescent, (2) 24", STD lamp	20	Mag-STD	50
F22HS	2	2	T12	F24T12/HO	Fluorescent, (2) 24", HO lamp	35	Mag-STD	97
F23LL	2	3	T8	F17T8	Fluorescent, (3) 24", T-8 lamp	17	Electronic	51
F23LE	2	3	T8	F17T8	Fluorescent, (3) 24", T-8 lamp	17	Mag-ES	68
F23SS	2	3	T12	F20T12	Fluorescent, (3) 24", STD lamp	20	Mag-STD	75
F24LL	2	4	T8	F17T8	Fluorescent, (4) 24", T-8 lamp	17	Electronic	62
F24LE	2	4	T8	F17T8	Fluorescent, (4) 24", T-8 lamp	17	Mag-ES	90
F24SS	2	4	T12	F20T12	Fluorescent, (4) 24", STD lamp	20	Mag-STD	100
F31LL	3	1	T8	F25T8	Fluorescent, (1) 36", T-8 lamp	25	Electronic	24
F31EL	3	1	T12	F30T12/ES	Fluorescent, (1) 36", ES lamp	25	Electronic	25
F31LE	3	1	T8	F25T8	Fluorescent, (1) 36", T-8 lamp	25	Mag-ES	33
F31ES	3	1	T12	F30T12/ES	Fluorescent, (1) 36", ES lamp	25	Mag-STD	41
F31SL	3	1	T12	F30T12	Fluorescent, (1) 36", STD lamp	30	Electronic	30
F31SS	3	1	T12	F30T12	Fluorescent, (1) 36", STD lamp	30	Mag-STD	46
F31HS	3	1	T12	F36T12/HO	Fluorescent, (1) 36", HO lamp	50	Mag-STD	65
F32LL/T	3	2	T8	F25T8	Fluorescent, (2) 36", T-8 lamp, Tandem wired 4 lamp bal	25	Electronic	45
F32EL	3	2	T12	F30T12/ES	Fluorescent, (2) 36", ES lamp	25	Electronic	50
F32LL	3	2	T8	F25T8	Fluorescent, (2) 36", T-8 lamp	25	Electronic	50
F32LE	3	2	T8	F25T8	Fluorescent, (2) 36", T-8 lamp	25	Mag-ES	65
F32EE	3	2	T12	F30T12/ES	Fluorescent, (2) 36", ES lamp	25	Mag-ES	66
F32ES	3	2	T12	F30T12/ES	Fluorescent, (2) 36", ES lamp	25	Mag-STD	73
F32SL	3	2	T12	F30T12	Fluorescent, (2) 36", STD lamp	30	Electronic	60
F32SE	3	2	T12	F30T12	Fluorescent, (2) 36", STD lamp	30	Mag-ES	74
F32SS	3	2	T12	F30T12	Fluorescent, (2) 36", STD lamp	30	Mag-STD	81
F32HS	3	2	T12	F36T12/HO	Fluorescent, (2) 36", HO, lamp	50	Mag-STD	121
F33LL	3	3	T8	F25T8	Fluorescent, (3) 36", T-8 Lamp	25	Electronic	69
F33EL	3	3	T12	F30T12/ES	Fluorescent, (3) 36", ES lamp	25	Electronic	72

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
F33LE	3	3	T8	F25T8	Fluorescent, (3) 36", T-8 lamp	25	Mag-ES	98
F33ES	3	3	T12	F30T12/ES	Fluorescent, (3) 36", ES lamp	25	Mag-STD	115
F33SL	3	3	T12	F30T12	Fluorescent, (3) 36", STD lamp	30	Electronic	86
F33SS	3	3	T12	F30T12	Fluorescent, (3) 36", STD lamp	30	Mag-STD	127
F33HS	3	3	T12	F36T12/HO	Fluorescent, (3) 36", HO, lamp	50	Mag-STD	186
F34LL	3	4	T8	F25T8	Fluorescent, (4) 36", T-8 lamp	25	Electronic	90
F34LE	3	4	T8	F25T8	Fluorescent, (4) 36", T-8 lamp	25	Mag-ES	130
F34ES	3	4	T12	F30T12/ES	Fluorescent, (4) 36", ES lamp	25	Mag-STD	146
F34SL	3	4	T12	F30T12	Fluorescent, (4) 36", STD lamp	30	Electronic	120
F34SE	3	4	T12	F30T12	Fluorescent, (4) 36", STD lamp	30	Mag-ES	148
F34SS	3	4	T12	F30T12	Fluorescent, (4) 36", STD lamp	30	Mag-STD	162
F34HS	3	4	T12	F36T12/HO	Fluorescent, (4) 36", HO, lamp	50	Mag-STD	242
F41EIS	4	1	T12	F48T12/ES	Fluorescent, (1) 48", ES IS lamp	30	Mag-STD	51
F41LL/T4	4	1	T8	F32T8	Fluorescent, (1) 48", T-8 lamp, Tandem Wired (4 lamp ba	32	Electronic	28
F41LL/T3	4	1	T8	F32T8	Fluorescent, (1) 48", T-8 lamp, Tandem Wired (3 lamp ba	32	Electronic	30
F41LL	4	1	T8	F32T8	Fluorescent, (1) 48", T-8 lamp	32	Electronic	30
F41LL/T2	4	1	T8	F32T8	Fluorescent, (1) 48", T-8 lamp, Tandem Wired (2 lamp ba	32	Electronic	31
F41LE	4	1	T8	F32T8	Fluorescent, (1) 48", T-8 lamp	32	Mag-ES	37
F41EL	4	1	T12	F40T12/ES	Fluorescent, (1) 48", ES lamp	34	Electronic	30
F41EE	4	1	T12	F40T12/ES	Fluorescent, (1) 48", ES lamp	34	Mag-ES	43
F41ES	4	1	T12	F40T12/ES	Fluorescent, (1) 48", ES lamp	34	Mag-STD	50
F41SL	4	1	T12	F40T12	Fluorescent, (1) 48", STD lamp	40	Electronic	37
F41SE	4	1	T12	F40T12	Fluorescent, (1) 48", STD lamp	40	Mag-ES	50
F41SE/2	4	1	T12	F40T12	Fluorescent, (1) 48", STD lamp, 2 ballasts (delamped)	40	Mag-ES	52
F41SS	4	1	T12	F40T12	Fluorescent, (1) 48", STD lamp	40	Mag-STD	57
F41TS	4	1	T10	F40T10	Fluorescent, (1) 48", T-10 lamp	40	Mag-STD	58
F41SIS	4	1	T12	F48T12	Fluorescent, (1) 48", STD IS lamp	40	Mag-STD	59
F41EHS	4	1	T12	F48T12/HO/ES	Fluorescent, (1) 48", ES HO lamp	55	Mag-STD	80
F41SHS	4	1	T12	F48T12/HO	Fluorescent, (1) 48", STD HO lamp	60	Mag-STD	85
F41SVS	4	1	T12	F48T12/VHO	Fluorescent, (1) 48", STD VHO lamp	110	Mag-STD	134
F42EIS	4	2	T12	F48T12/ES	Fluorescent, (2) 48", ES IS lamp	30	Mag-STD	81
F42LL/T	4	2	T8	F32T8	Fluorescent, (2) 48", T-8 lamp, Tandem Wired	32	Electronic	55
F42LL	4	2	T8	F32T8	Fluorescent, (2) 48", T-8 lamp	32	Electronic	62
F42LE	4	2	T8	F32T8	Fluorescent, (2) 48", T-8 lamp	32	Mag-ES	71
F42EL	4	2	T12	F40T12/ES	Fluorescent, (2) 48", ES lamp	34	Electronic	59
F42EE	4	2	T12	F40T12/ES	Fluorescent, (2) 48", ES lamp	34	Mag-ES	72

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
F42EE/2	4	2	T12	F40T12/ES	Fluorescent, (2) 48", ES lamp, 2 Ballasts (delamped)	34	Mag-ES	76
F42ES	4	2	T12	F40T12/ES	Fluorescent, (2) 48", ES lamp	34	Mag-STD	82
F42SL	4	2	T12	F40T12	Fluorescent, (2) 48", STD lamp	40	Electronic	70
F42SE	4	2	T12	F40T12	Fluorescent, (2) 48", STD lamp	40	Mag-ES	86
F42SE/2	4	2	T12	F40T12	Fluorescent, (2) 48", STD lamp, 2 ballasts (delamped)	40	Mag-ES	92
F42SS	4	2	T12	F40T12	Fluorescent, (2) 48", STD lamp	40	Mag-STD	96
F42SIS	4	2	T12	F48T12	Fluorescent, (2) 48", STD IS lamp	40	Mag-STD	98
F42EHS	4	2	T12	F48T12/HO/ES	Fluorescent, (2) 48", ES HO lamp	55	Mag-STD	131
F42SHS	4	2	T12	F48T12/HO	Fluorescent, (2) 48", STD HO lamp	60	Mag-STD	145
F42SVS	4	2	T12	F48T12/VHO	Fluorescent, (2) 48", STD VHO lamp	110	Mag-STD	242
F43EIS	4	3	T12	F48T12/ES	Fluorescent, (3) 48", ES IS lamp	30	Mag-STD	132
F43LL	4	3	T8	F32T8	Fluorescent, (3) 48", T-8 lamp	32	Electronic	89
F43LE	4	3	T8	F32T8	Fluorescent, (3) 48", T-8 lamp	32	Mag-ES	108
F43EL	4	3	T12	F40T12/ES	Fluorescent, (3) 48", ES lamp	34	Electronic	90
F43EE	4	3	T12	F40T12/ES	Fluorescent, (3) 48", ES lamp	34	Mag-ES	115
F43ES	4	3	T12	F40T12/ES	Fluorescent, (3) 48", ES lamp	34	Mag-STD	132
F43SL	4	3	T12	F40T12	Fluorescent, (3) 48", STD lamp	40	Electronic	105
F43SE	4	3	T12	F40T12	Fluorescent, (3) 48", STD lamp	40	Mag-ES	136
F43SS	4	3	T12	F40T12	Fluorescent, (3) 48", STD lamp	40	Mag-STD	153
F43SIS	4	3	T12	F48T12	Fluorescent, (3) 48", STD IS lamp	40	Mag-STD	157
F43EHS	4	3	T12	F48T12/HO/ES	Fluorescent, (3) 48", ES HO lamp	55	Mag-STD	211
F43SHS	4	3	T12	F48T12/HO	Fluorescent, (3) 48", STD HO lamp	60	Mag-STD	230
F43SVS	4	3	T12	F48T12/VHO	Fluorescent, (3) 48", STD VHO lamp	110	Mag-STD	376
F44EIS	4	4	T12	F48T12/ES	Fluorescent, (4) 48", ES IS lamp	30	Mag-STD	162
F44LL	4	4	T8	F32T8	Fluorescent, (4) 48", T-8 lamp	32	Electronic	110
F44LE	4	4	T8	F32T8	Fluorescent, (4) 48", T-8 lamp	32	Mag-ES	142
F44EL	4	4	T12	F40T12/ES	Fluorescent, (4) 48", ES lamp	34	Electronic	120
F44EE	4	4	T12	F40T12/ES	Fluorescent, (4) 48", ES lamp	34	Mag-ES	144
F44EE/4	4	4	T12	F40T12/ES	Fluorescent, (4) 48", ES lamp, 4 Ballasts (delamped)	34	Mag-ES	152
F44ES	4	4	T12	F40T12/ES	Fluorescent, (4) 48", ES lamp	34	Mag-STD	164
F44SL	4	4	T12	F40T12	Fluorescent, (4) 48", STD lamp	40	Electronic	140
F44SE	4	4	T12	F40T12	Fluorescent, (4) 48", STD lamp	40	Mag-ES	172
F44SS	4	4	T12	F40T12	Fluorescent, (4) 48", STD lamp	40	Mag-STD	192
F44SIS	4	4	T12	F48T12	Fluorescent, (4) 48", STD IS lamp	40	Mag-STD	196
F44EHS	4	4	T12	F48T12/HO/ES	Fluorescent, (4) 48", ES HO lamp	55	Mag-STD	262
F44SHS	4	4	T12	F48T12/HO	Fluorescent, (4) 48", STD HO lamp	60	Mag-STD	290

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
F44SVS	4	4	T12	F48T12/VHO	Fluorescent, (4) 48", STD VHO lamp	110	Mag-STD	484
F46EL	4	6	T12	F40T12/ES	Fluorescent, (6) 48", ES lamp	34	Electronic	179
F46ES	4	6	T12	F40T12/ES	Fluorescent, (6) 48", ES lamp	34	Mag-STD	246
F46SL	4	6	T12	F40T12	Fluorescent, (6) 48", STD lamp	40	Electronic	210
F46SE	4	6	T12	F40T12	Fluorescent, (6) 48", STD lamp	40	Mag-ES	258
F46SS	4	6	T12	F40T12	Fluorescent, (6) 48", STD lamp	40	Mag-STD	288
F48EE	4	8	T12	F40T12/ES	Fluorescent, (8) 48", ES lamp	34	Mag-ES	288
F48ES	4	8	T12	F40T12/ES	Fluorescent, (8) 48", ES lamp	34	Mag-STD	328
F48SS	4	8	T12	F40T12	Fluorescent, (8) 48", STD lamp	40	Mag-STD	384
F51LL	5	1	T8	F40T8	Fluorescent, (1) 60", T-8 lamp	40	Electronic	44
F51LE	5	1	T8	F40T8	Fluorescent, (1) 60", T-8 lamp	40	Mag-ES	50
F51SL	5	1	T12	F60T12	Fluorescent, (1) 60", STD lamp	50	Electronic	44
F51SE	5	1	T12	F60T12	Fluorescent, (1) 60", STD lamp	50	Mag-ES	63
F51SS	5	1	T12	F60T12	Fluorescent, (1) 60", STD lamp	50	Mag-STD	65
F51SHS	5	1	T12	F60T12/HO	Fluorescent, (1) 60", STD HO lamp	75	Mag-STD	90
F52LL	5	2	T8	F40T8	Fluorescent, (2) 60", T-8 lamp	40	Electronic	72
F52LE	5	2	T8	F40T8	Fluorescent, (2) 60", T-8 lamp	40	Mag-ES	92
F52SE	5	2	T12	F60T12	Fluorescent, (2) 60", STD lamp	50	Mag-ES	126
F52SS	5	2	T12	F60T12	Fluorescent, (2) 60", STD lamp	50	Mag-STD	130
F52SHS	5	2	T12	F60T12/HO	Fluorescent, (2) 60", STD HO lamp	75	Mag-STD	180
F53LL	5	3	T8	F40T8	Fluorescent, (3) 60", T-8 lamp	40	Electronic	107
F53LE	5	3	T8	F40T8	Fluorescent, (3) 60", T-8 lamp	40	Mag-ES	142
F54LE	5	4	T8	F40T8	Fluorescent, (4) 60", T-8 lamp	40	Mag-ES	184
F61SS	6	1	T12	F72T12	Fluorescent, (1) 72", STD lamp	55	Mag-STD	70
F61SHS	6	1	T12	F72T12/HO	Fluorescent, (1) 72", STD HO lamp	85	Mag-STD	135
F62SL	6	2	T12	F72T12	Fluorescent, (2) 72", STD lamp	55	Electronic	105
F62SE	6	2	T12	F72T12	Fluorescent, (2) 72", STD lamp	55	Mag-ES	122
F62SS	6	2	T12	F72T12	Fluorescent, (2) 72", STD lamp	55	Mag-STD	132
F62SHL	6	2	T12	F72T12/HO	Fluorescent, (2) 72", STD HO lamp	85	Electronic	160
F62SHE	6	2	T12	F72T12/HO	Fluorescent, (2) 72", STD HO lamp	85	Mag-ES	187
F62SHS	6	2	T12	F72T12/HO	Fluorescent, (2) 72", STD HO lamp	85	Mag-STD	219
F63SS	6	3	T12	F72T12	Fluorescent, (3) 72", STD lamp	55	Mag-STD	202
F81LL	8	1	T8	F96T8	Fluorescent, (1) 96", T-8 lamp	59	Electronic	52
F81EL	8	1	T12	F96T12/ES	Fluorescent, (1) 96", ES lamp	60	Electronic	53
F81EE	8	1	T12	F96T12/ES	Fluorescent, (1) 96", ES lamp	60	Mag-ES	77
F81ES	8	1	T12	F96T12/ES	Fluorescent, (1) 96", ES lamp	60	Mag-STD	83

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
F81SL	8	1	T12	F96T12	Fluorescent, (1) 96", STD lamp	75	Electronic	65
F81SE	8	1	T12	F96T12	Fluorescent, (1) 96", STD lamp	75	Mag-ES	90
F81SS	8	1	T12	F96T12	Fluorescent, (1) 96", STD lamp	75	Mag-STD	100
F46EE	4	6	T12	F40T12/ES	Fluorescent, (6) 48", ES lamp	34	Mag-ES	216
F81EHL	8	1	T12	F96T12/HO/ES	Fluorescent, (1) 96", ES HO lamp	95	Electronic	80
F81EHE	8	1	T12	F96T12/HO/ES	Fluorescent, (1) 96", ES HO lamp	95	Mag-ES	106
F81EHS	8	1	T12	F96T12/HO/ES	Fluorescent, (1) 96", ES HO lamp	95	Mag-STD	125
F81SHS	8	1	T12	F96T12/HO	Fluorescent, (1) 96", STD HO lamp	110	Mag-STD	140
F81EVS	8	1	T12	F96T12/VHO/ES	Fluorescent, (1) 96", ES VHO lamp	185	Mag-STD	200
F81SVS	8	1	T12	F96T12/VHO	Fluorescent, (1) 96", STD VHO lamp	215	Mag-STD	230
F82LL	8	2	T8	F96T8	Fluorescent, (2) 96", T-8 lamp	59	Electronic	111
F82EL	8	2	T12	F96T12/ES	Fluorescent, (2) 96", ES lamp	60	Electronic	109
F82EE	8	2	T12	F96T12/ES	Fluorescent, (2) 96", ES lamp	60	Mag-ES	123
F82ES	8	2	T12	F96T12/ES	Fluorescent, (2) 96", ES lamp	60	Mag-STD	138
F82SL	8	2	T12	F96T12	Fluorescent, (2) 96", STD lamp	75	Electronic	136
F82SE	8	2	T12	F96T12	Fluorescent, (2) 96", STD lamp	75	Mag-ES	158
F82SS	8	2	T12	F96T12	Fluorescent, (2) 96", STD lamp	75	Mag-STD	173
F82LHL	8	2	T8	F96T8/HO	Fluorescent, (1) 96", T-8 HO lamp	86	Electronic	162
F82EHL	8	2	T12	F96T12/HO/ES	Fluorescent, (2) 96", ES HO lamp	95	Electronic	169
F82EHE	8	2	T12	F96T12/HO/ES	Fluorescent, (2) 96", ES HO lamp	95	Mag-ES	207
F82EHS	8	2	T12	F96T12/HO/ES	Fluorescent, (2) 96", ES HO lamp	95	Mag-STD	227
F82SHL	8	2	T12	F96T12/HO	Fluorescent, (2) 96", STD HO lamp	110	Electronic	200
F82SHE	8	2	T12	F96T12/HO	Fluorescent, (2) 96", STD HO lamp	110	Mag-ES	237
F82SHS	8	2	T12	F96T12/HO	Fluorescent, (2) 96", STD HO lamp	110	Mag-STD	257
F82EVS	8	2	T12	F96T12/VHO/ES	Fluorescent, (2) 96", ES VHO lamp	185	Mag-STD	390
F82SVS	8	2	T12	F96T12/VHO	Fluorescent, (2) 96", STD VHO lamp	215	Mag-STD	450
F83LL	8	3	T8	F96T8	Fluorescent, (3) 96", T-8 lamp	59	Electronic	168
F83EL	8	3	T12	F96T12/ES	Fluorescent, (3) 96", ES lamp	60	Electronic	158
F83EE	8	3	T12	F96T12/ES	Fluorescent, (3) 96", ES lamp	60	Mag-ES	210
F83ES	8	3	T12	F96T12/ES	Fluorescent, (3) 96", ES lamp	60	Mag-STD	221
F83SL	8	3	T12	F96T12	Fluorescent, (3) 96", STD lamp	75	Electronic	195
F83SE	8	3	T12	F96T12	Fluorescent, (3) 96", STD lamp	75	Mag-ES	264
F83SS	8	3	T12	F96T12	Fluorescent, (3) 96", STD lamp	75	Mag-STD	273
F83EHS	8	3	T12	F96T12/HO/ES	Fluorescent, (3) 96", ES HO lamp	95	Mag-STD	352
F83SHS	8	3	T12	F96T12/HO	Fluorescent, (3) 96", STD HO lamp	110	Mag-STD	397
F83EVS	8	3	T12	F96T12/VHO/ES	Fluorescent, (3) 96", ES VHO lamp	185	Mag-STD	590
F83SVS	8	3	T12	F96T12/VHO	Fluorescent, (3) 96", STD VHO lamp	215	Mag-STD	680

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
F84LL	8	4	T8	F96T8	Fluorescent, (4) 96", T-8 lamp	59	Electronic	216
F84EL	8	4	T12	F96T12/ES	Fluorescent, (4) 96", ES lamp	60	Electronic	210
F84EE	8	4	T12	F96T12/ES	Fluorescent, (4) 96", ES lamp	60	Mag-ES	246
F84ES	8	4	T12	F96T12/ES	Fluorescent, (4) 96", ES lamp	60	Mag-STD	276
F84SL	8	4	T12	F96T12	Fluorescent, (4) 96", STD lamp	75	Electronic	260
F84SE	8	4	T12	F96T12	Fluorescent, (4) 96", STD lamp	75	Mag-ES	316
F84SS	8	4	T12	F96T12	Fluorescent, (4) 96", STD lamp	75	Mag-STD	346
F84EHL	8	4	T12	F96T12/HO/ES	Fluorescent, (4) 96", ES HO lamp	95	Electronic	360
F84EHE	8	4	T12	F96T12/HO/ES	Fluorescent, (4) 96", ES HO lamp	95	Mag-ES	414
F84EHS	8	4	T12	F96T12/HO/ES	Fluorescent, (4) 96", ES HO lamp	95	Mag-STD	454
F84SHL	8	4	T12	F96T12/HO	Fluorescent, (4) 96", STD HO lamp	110	Electronic	386
F84SHE	8	4	T12	F96T12/HO	Fluorescent, (4) 96", STD HO lamp	110	Mag-ES	474
F84SHS	8	4	T12	F96T12/HO	Fluorescent, (4) 96", STD HO lamp	110	Mag-STD	514
F84EVS	8	4	T12	F96T12/VHO/ES	Fluorescent, (4) 96", ES VHO lamp	185	Mag-STD	780
F84SVS	8	4	T12	F96T12/VHO	Fluorescent, (4) 96", STD VHO lamp	215	Mag-STD	900
FU1LL		1	T8	FU32T8	Fluorescent, (1) T8 U-Tube, STD lamp	32	Electronic	32
FU1LE		1	T8	FU32T8	Fluorescent, (1) T8 U-Tube, STD lamp	32	Mag-ES	37
FU1EL		1	T12	FU40T12/ES	Fluorescent, (1) U-Tube, ES lamp	35	Electronic	31
FU1EE		1	T12	FU40T12/ES	Fluorescent, (1) U-Tube, ES lamp	35	Mag-ES	43
FU1ES		1	T12	FB40T12/ES	Fluorescent, (1) U-Tube, ES lamp	35	Mag-STD	50
FU1SL		1	T12	FU40T12	Fluorescent, (1) U-Tube, STD lamp	40	Electronic	38
FU1SE		1	T12	FU40T12	Fluorescent, (1) U-Tube, STD lamp	40	Mag-ES	50
FU1SS		1	T12	FB40T12	Fluorescent, (1) U-Tube, STD lamp	40	Mag-STD	57
FU2LL		2	T8	FU32T8	Fluorescent, (2) T8 U-Tube, STD lamp	32	Electronic	62
FU2LE		2	T8	FU32T8	Fluorescent, (2) T8 U-Tube, STD lamp	32	Mag-ES	71
FU2EL		2	T12	FU40T12/ES	Fluorescent, (2) U-Tube, ES lamp	35	Electronic	60
FU2EE		2	T12	FU40T12/ES	Fluorescent, (2) U-Tube, ES lamp	35	Mag-ES	72
FU2ES		2	T12	FB40T12/ES	Fluorescent, (2) U-Tube, ES lamp	35	Mag-STD	82
FU2SL		2	T12	FU40T12	Fluorescent, (2) U-Tube, STD lamp	40	Electronic	72
FU2SE		2	T12	FU40T12	Fluorescent, (2) U-Tube, STD lamp	40	Mag-ES	86
FU2SS		2	T12	FB40T12	Fluorescent, (2) U-Tube, STD lamp	40	Mag-STD	96
FU3LL		3	T8	FU32T8	Fluorescent, (3) T8 U-Tube, STD lamp	32	Electronic	94
FU3EL		3	T12	FU40T12/ES	Fluorescent, (3) U-Tube, ES lamp	35	Electronic	107
FU3EE		3	T12	FU40T12/ES	Fluorescent, (3) U-Tube, ES lamp	35	Mag-ES	115
FU3ES		3	T12	FU40T12/ES	Fluorescent, (3) U-Tube, ES lamp	35	Mag-STD	132
FU3SL		3	T12	FU40T12	Fluorescent, (3) U-Tube, STD lamp	40	Electronic	107
FU3SE		3	T12	FU40T12	Fluorescent, (3) U-Tube, STD lamp	40	Mag-ES	136

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
FU3SS		3	T12	FU40T12	Fluorescent, (3) U-Tube, ES lamp	40	Mag-STD	140
FU3SS		3	T12	FB40T12	Fluorescent, (3) U-Tube, STD lamp	40	Mag-STD	153
FU4LL		4	T8	FU32T8	Fluorescent, (4) T8 U-Tube, STD lamp	32	Electronic	108
FU4ES		4	T12	FB40T12/ES	Fluorescent, (4) U-Tube, ES lamp	35	Mag-STD	164
FU4SS		4	T12	FB40T12	Fluorescent, (4) U-Tube, STD lamp	40	Mag-STD	192
FC6/1		1	T9	FC6T9	Fluorescent, (1) 6" circular lamp	20	Mag-STD	22
FC20		1	T12	FC20W	Fluorescent, Circlite, (1) 20W lamp	20	Mag-STD	22
FC22		1	T12	FC22W	Fluorescent, Circlite, (1) 22W lamp	22	Mag-STD	24
FC8/1		1	T9	FC8T9	Fluorescent, (1) 8" circular lamp	22	Mag-STD	35
FC27		1	T12	FC27W	Fluorescent, Circlite, (1) 27W lamp	27	Mag-STD	29
FC12/1		1	T9	FC12T9	Fluorescent, (1) 12" circular lamp	32	Mag-STD	34
FC16/1		1	T9	FC16T9	Fluorescent, (1) 16" circular lamp	40	Mag-STD	44
FC8/2		2	T9	FC8T9	Fluorescent, (2) 8" circular lamp	22	Mag-STD	70
FC12/2		2	T9	FC12T9	Fluorescent, (2) 12" circular lamp	32	Mag-STD	68
CFT5/1		1		CFT5W	Compact Fluorescent, twin, (1) 5W lamp	5	Mag-STD	9
CF7/INT		1		CFI7W	Compact Fluorescent, Integral, (1) 7W lamp	7	Mag-STD	9
CFT7/1		1		CFT7W	Compact Fluorescent, twin, (1) 7W lamp	7	Mag-STD	11
CF9/INT		1		CFI9W	Compact Fluorescent, Integral, (1) 9W lamp	9	Mag-STD	11
CFQ9/1		1		CFQ9W	Compact Fluorescent, quad, (1) 9W lamp	9	Mag-STD	13
CFT9/1		1		CFT9W	Compact Fluorescent, twin, (1) 9W lamp	9	Mag-STD	13
CF10/2D		1		CFD10W	Compact Fluorescent, 2D, (1) 10W lamp	10	Mag-STD	12
CFQ10A/1		1		CFQ10W	Compact Fluorescent, quad, (1) 10W lamp, Autotransforme	10	Mag-STD	16
CF11/GL		1		CFG11W	Compact Fluorescent, Globe, (1) 11W lamp	11	Mag-STD	11
CF13/CAP		1		CFC13W	Compact Fluorescent, Capsule, (1) 13W lamp	13	Mag-STD	13
CF13/INT		1		CFI13W	Compact Fluorescent, Integral, (1) 13W lamp	13	Mag-STD	15
CF15/GL		1		CFG15W	Compact Fluorescent, Globe, (1) 15W lamp	13	Mag-STD	15
CFT13/1		1		CFT13W	Compact Fluorescent, twin, (1) 13W lamp	13	Mag-STD	17
CFQ13/1		1		CFQ13W	Compact Fluorescent, quad, (1) 13W lamp	13	Mag-STD	18
CFQ15/1		1		CFQ15W	Compact Fluorescent, quad, (1) 15W lamp	15	Mag-STD	20
CF16/2D		1		CFD16W	Compact Fluorescent, 2D, (1) 16W lamp	16	Mag-STD	18
CF18/CAP		1		CFC18W	Compact Fluorescent, Capsule, (1) 18W lamp	18	Mag-STD	18
BX18/1		1		FT18T5	Fluorescent, Biax, (1) 18W lamp	18	Mag-STD	20
CFQ18R/1		1		CFQ18W	Compact Fluorescent, quad, (1) 18W lamp, Reactor	18	Mag-STD	22
CFT18IS/1		1		CFT18W	Compact Fluorescent, twin, instant start (1) 18W lamp	18	Mag-STD	22
CFQ18A/1		1		CFQ18W	Compact Fluorescent, quad, (1) 18W lamp, Autotransforme	18	Mag-STD	25
CFT18RS/1		1		CFT18W	Compact Fluorescent, twin, rapid start (1) 18W lamp	18	Mag-STD	25
CF20/INT		1		CFI20W	Compact Fluorescent, Integral, (1) 20W lamp	20	Mag-STD	20

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
CF26/INT		1		CFI26W	Compact Fluorescent, Integral, (1) 26W lamp	20	Mag-STD	26
CFQ20/1		1		CFQ20W	Compact Fluorescent, quad, (1) 20W lamp	20	Mag-STD	27
CF21/2D		1		CFD21W	Compact Fluorescent, 2D, (1) 21W lamp	21	Mag-STD	23
BX24/1		1		FT24T5	Fluorescent, Biax, (1) 24W lamp	24	Mag-STD	26
CFQ26/1		1		CFQ26W	Compact Fluorescent, quad, (1) 26W lamp	26	Electronic	25
CFQ26R/1		1		CFQ26W	Compact Fluorescent, quad, (1) 26W lamp, Reactor	26	Mag-STD	31
CFQ26A/1		1		CFQ26W	Compact Fluorescent, quad, (1) 26W lamp, Autotransforme	26	Mag-STD	37
CFT27IS/1		1		CFT27W	Compact Fluorescent, twin, instant start (1) 27W lamp	27	Mag-STD	28
CFT27RS/1		1		CFT27W	Compact Fluorescent, twin, rapid start (1) 27W lamp	27	Mag-STD	32
CFQ27/1		1		CFQ27W	Compact Fluorescent, quad, (1) 27W lamp	27	Mag-STD	34
CF28/2D		1		CFD28W	Compact Fluorescent, 2D, (1) 28W lamp	28	Mag-STD	30
BX36/1		1		FT36T5	Fluorescent, Biax, (1) 36W lamp	36	Mag-STD	40
CFT36/1		1		CFT36W	Compact Fluorescent, twin, (1) 36W lamp	36	Mag-STD	51
CF38/2D		1		CFD38W	Compact Fluorescent, 2D, (1) 38W lamp	38	Mag-STD	44
CFT40/1		1		CFT40W	Compact Fluorescent, twin, (1) 40W lamp	40	Mag-STD	48
CFT50/1		1		CFT50W	Compact Fluorescent, twin, (1) 50W lamp	50	Mag-STD	46
CFT5/2		2		CFT5W	Compact Fluorescent, twin, (2) 5W lamp	5	Mag-STD	14
CFT7/2		2		CFT7W	Compact Fluorescent, twin, (2) 7W lamp	7	Mag-STD	18
CFT9/2		2		CFT9W	Compact Fluorescent, twin, (2) 9W lamp	9	Mag-STD	22
CFQ13/2		2		CFQ13W	Compact Fluorescent, quad, (2) 13W lamp	13	Mag-STD	34
CFT13/2		2		CFT13W	Compact Fluorescent, twin, (2) 13W lamp	13	Mag-STD	34
CFQ18/2		2		CFQ18W	Compact Fluorescent, quad, (2) 18W lamp	18	Mag-STD	42
CFT18IS/2		2		CFT18W	Compact Fluorescent, twin, instant start (2) 18W lamp	18	Mag-STD	46
CFT18RS/2		2		CFT18W	Compact Fluorescent, twin, rapid start (2) 18W lamp	18	Mag-STD	46
CFQ18/4		2		CFQ18W	Compact Fluorescent, quad, (4) 18W lamp	18	Mag-STD	84
CFQ26/2		2		CFQ26W	Compact Fluorescent, quad, (2) 26W lamp	26	Electronic	50
CFT27IS/2		2		CFT27W	Compact Fluorescent, twin, instant start (2) 27W lamp	27	Mag-STD	60
CFT27RS/2		2		CFT27W	Compact Fluorescent, twin, rapid start (2) 27W lamp	27	Mag-STD	66
CFT36/2		2		CFT36W	Compact Fluorescent, twin, (2) 36W lamp	36	Mag-STD	88
CFT40/2		2		CFT40W	Compact Fluorescent, twin, (2) 40W lamp	40	Mag-STD	82
CFT50/2		2		CFT50W	Compact Fluorescent, twin, (2) 50W lamp	50	Mag-STD	82
ELED2/1		1		LED2W	EXIT Light Emitting Diode, (1) 2W lamp, Single Sided	2		2
EI5/1		1			EXIT Incandescent, (1) 5W lamp	5		5
EMFL5/1		1		F5TT	EXIT Emergency Fluorescent, (1) 5W Twin tube lamp	5		20
EFL7/1		1		F7TT	EXIT Fluorescent, (1) 7W Twin tube lamp	7		10
EMFL7/1		1		F7TT	EXIT Emergency Fluorescent, (1) 7W Twin tube lamp	7		16
EFL8/1		1		F8T5	EXIT Fluorescent, (1) 8W T5 Min. Bipin lamp	8		10

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
EMFL8/1		1		F8T5	EXIT Emergency Fluorescent, (1) 8W T5 Min. Bipin lamp	8		14
EI15/1		1			EXIT Incandescent, (1) 15W lamp	15		15
EI25/1		1			EXIT Incandescent, (1) 25W lamp	25		25
ELED2/2		2		LED2W	EXIT Light Emitting Diode, (2) 2W lamp, Dual Sided	2		4
EI5/2		2			EXIT Incandescent, (2) 5W lamp	5		10
EFL5/2		2		F5TT	EXIT Fluorescent, (2) 5W Twin tube lamp	5		16
EMFL5/2		2		F5TT	EXIT Emergency Fluorescent, (2) 5W Twin tube lamp	5		22
EFL7/2		2		F7TT	EXIT Fluorescent, (2) 7W Twin tube lamp	7		19
EFL8/2		2		F8T5	EXIT Fluorescent, (2) 8W T5 Min. Bipin lamp	8		20
EMFL8/2		2		F8T5	EXIT Emergency Fluorescent, (2) 8W T5 Min. Bipin lamp	8		24
EI15/2		2			EXIT Incandescent, (2) 15W lamp	15		30
EI25/2		2			EXIT Incandescent, (2) 25W lamp	25		50
EI50/2		2			EXIT Incandescent, (2) 50W lamp	50		100
H45/1		1		H45	Halogen Incandescent, (1) 45W lamp	45		45
H50/1		1		H50	Halogen Incandescent, (1) 50W lamp	50		50
H52/1		1		H52	Halogen Incandescent, (1) 52W lamp	52		52
H72/1		1		H72	Halogen Incandescent, (1) 72W lamp	72		72
H90/1		1		H90	Halogen Incandescent, (1) 90W lamp	90		90
HPS35/1		1		HPS35	High Pressure Sodium, (1) 35W lamp	35		44
HPS50/1		1		HPS50	High Pressure Sodium, (1) 50W lamp	50		61
HPS70/1		1		HPS70	High Pressure Sodium, (1) 70W lamp	70		83
HPS100/1		1		HPS100	High Pressure Sodium, (1) 100W lamp	100		116
HPS150/1		1		HPS150	High Pressure Sodium, (1) 150W lamp	150		173
HPS200/1		1		HPS200	High Pressure Sodium, (1) 200W lamp	200		240
HPS250/1		1		HPS250	High Pressure Sodium, (1) 250W lamp	250		302
HPS310/1		1		HPS310	High Pressure Sodium, (1) 310W lamp	310		355
HPS360/1		1		HPS360	High Pressure Sodium, (1) 360W lamp	360		395
HPS400/1		1		HPS400	High Pressure Sodium, (1) 400W lamp	400		469
HPS1000/1		1		HPS1000	High Pressure Sodium, (1) 1000W lamp	1000		1090
I25/1		1		I25	Incandescent, (1) 25W lamp	25		25
I40E/1		1		I40/ES	Incandescent, (1) 40W ES lamp	34		34
I40EL/1		1		I40/ES/LL	Incandescent, (1) 40W ES/LL lamp	34		34
I40/1		1		I40	Incandescent, (1) 40W lamp	40		40
I50/1		1		I50	Incandescent, (1) 50W lamp	50		50
I60E/1		1		I60/ES	Incandescent, (1) 60W ES lamp	52		52
I60EL/1		1		I60/ES/LL	Incandescent, (1) 60W ES/LL lamp	52		52
I60/1		1		I60	Incandescent, (1) 60W lamp	60		60

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
I75E/1		1		I75/ES	Incandescent, (1) 75W ES lamp	67		67
I75EL/1		1		I75/ES/LL	Incandescent, (1) 75W ES/LL lamp	67		67
I75/1		1		I75	Incandescent, (1) 75W lamp	75		75
I100E/1		1		I100/ES	Incandescent, (1) 100W ES lamp	90		90
I100EL/1		1		I100/ES/LL	Incandescent, (1) 100W ES/LL lamp	90		90
I100/1		1		I100	Incandescent, (1) 100W lamp	100		100
I150E/1		1		I150/ES	Incandescent, (1) 150W ES lamp	135		135
I150EL/1		1		I150/ES/LL	Incandescent, (1) 150W ES/LL lamp	135		135
I150/1		1		I150	Incandescent, (1) 150W lamp	150		150
I200/1		1		I200	Incandescent, (1) 200W lamp	200		200
I200L/1		1		I200/LL	Incandescent, (1) 200W LL lamp	200		200
I250/1		1		I250	Incandescent, (1) 250W lamp	250		250
I300/1		1		I300	Incandescent, (1) 300W lamp	300		300
I400/1		1		I400	Incandescent, (1) 400W lamp	400		400
I500/1		1		I500	Incandescent, (1) 500W lamp	500		500
I55/1		1		I55	Incandescent, (1) 55W lamp	500		500
I1000/1		1		I1000	Incandescent, (1) 1000W lamp	1000		1000
I40/2		2		I40	Incandescent, (2) 40W lamp	40		80
I50/2		2		I50	Incandescent, (2) 50W lamp	50		100
I60/2		2		I60	Incandescent, (2) 60W lamp	60		120
I75/2		2		I75	Incandescent, (2) 75W lamp	75		150
I100/2		2		I100	Incandescent, (2) 100W lamp	100		200
I150/2		2		I150	Incandescent, (2) 150W lamp	150		300
I100/3		3		I100	Incandescent, (3) 100W lamp	100		300
I100/4		4		I100	Incandescent, (4) 100W lamp	100		400
MH32/1		1		MH32	Metal Halide, (1) 32W lamp	32		40
MH50/1		1		MH50	Metal Halide, (1) 50W lamp	50		72
MH70/1		1		MH70	Metal Halide, (1) 70W lamp	70		89
MH100/1		1		MH100	Metal Halide, (1) 100W lamp	100		129
MH150/1		1		MH150	Metal Halide, (1) 150W lamp	150		185
MH175/1		1		MH175	Metal Halide, (1) 175W lamp	175		210
MH250/1		1		MH250	Metal Halide, (1) 250W lamp	250		295
MH400/1		1		MH400	Metal Halide, (1) 400W lamp	400		461
MH1000/1		1		MH1000	Metal Halide, (1) 1000W lamp	1000		1070
MH1500/1		1		MH1500	Metal Halide, (1) 1500W lamp	1500		1610
MV40/1		1		MV40	Mercury Vapor, (1) 40W lamp	40		51
MV50/1		1		MV50	Mercury Vapor, (1) 50W lamp	50		63

Code	Lamp Length	Lamps per fixture	Lamp Type	Lamp designation	Lamp Description	W/lamp	Ballast type	Watts per fixture
MV75/1		1		MV75	Mercury Vapor, (1) 75W lamp	75		88
MV100/1		1		MV100	Mercury Vapor, (1) 100W lamp	100		119
MV175/1		1		MV175	Mercury Vapor, (1) 175W lamp	175		197
MV250/1		1		MV250	Mercury Vapor, (1) 250W lamp	250		285
MV400/1		1		MV400	Mercury Vapor, (1) 400W lamp	400		450
MV700/1		1		MV700	Mercury Vapor, (1) 700W lamp	700		780
MV1000/1		1		MV1000	Mercury Vapor, (1) 1000W lamp	1000		1080